POWER PLANT ENGINEERING

Established Over 29 Years

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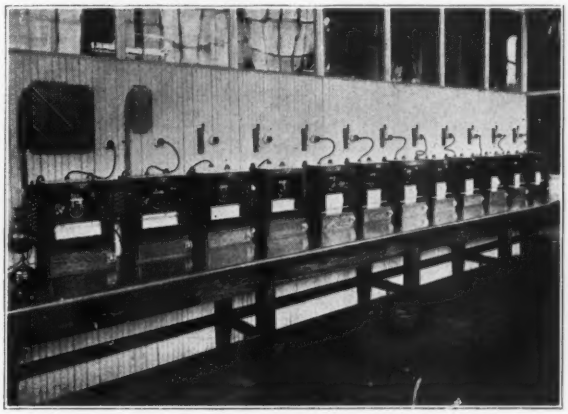
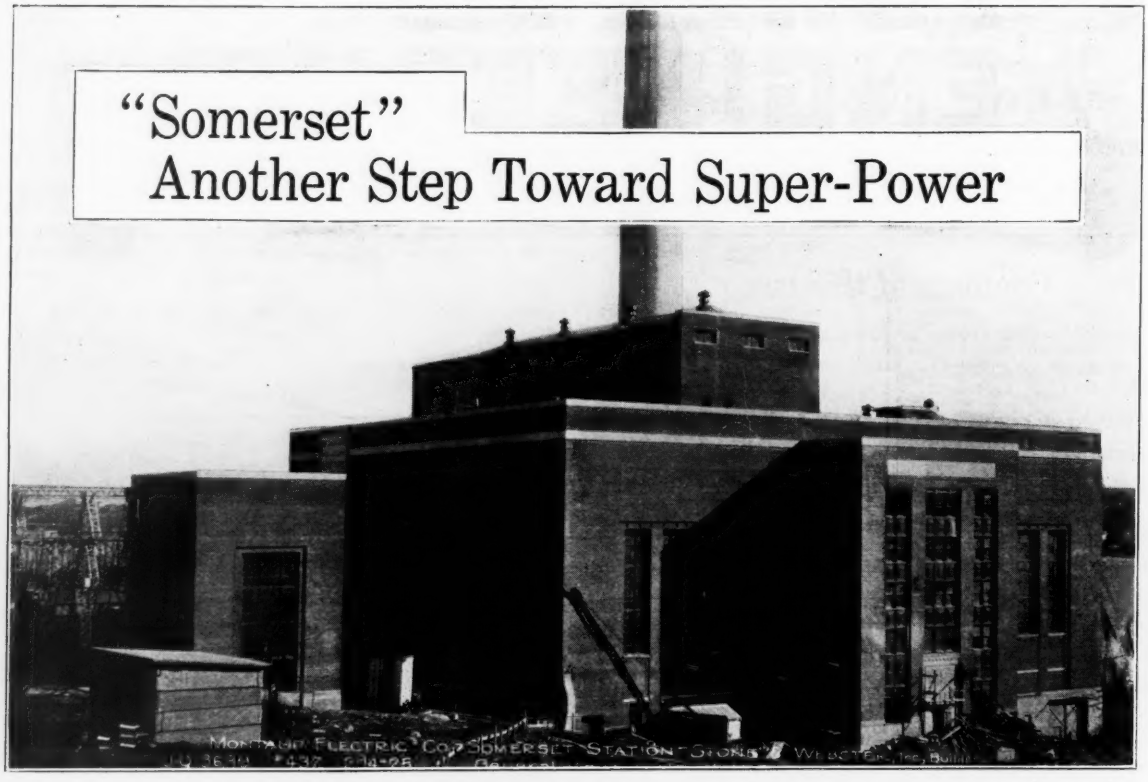


Electricity Speaks for Temperature

ELECTRICITY is the most versatile interpreter we have today. Not only does it tell its own story in a thousand different ways but it speaks for all other physical entities as well. Whether you want to measure heat, work, flow, angular velocity, stress or strain, chemical action, in fact, almost any physical quantity you can think of, electricity will do it for you. In the measurement of temperature, for instance, we rarely see the thermometer these days. What we see is a potentiometer or a millivoltmeter or an ammeter, calibrated to read in terms of temperature. This makes things much easier. Take the 12 temperature recorders shown in the above photograph for instance. The furnaces whose temperature they keep tab on, are located at different points throughout the plant, widely removed from the quiet room in which the recorders are installed. It is no longer necessary to risk one's neck climbing on top of a furnace to look at a thermometer. Electricity does it much more quickly than we can, and brings the required information to us wherever we may be, quickly, quietly and accurately. In the article on page 395 other roles of electricity in the measurement of physical quantities are described.

IT WOULD take a pretty sensitive scale or balance to detect a difference of one-tenth of an ounce in a mass weighing 750 lb. Yet in the balancing of generator and turbine rotors with modern balancing machines, no difficulty is encountered in measuring an unbalance of this magnitude—in fact it is possible to detect unbalances far smaller than those which can be tolerated in actual operation. The article on page 388 explains this in greater detail.

"Somerset" Another Step Toward Super-Power



NEW BASE LOAD STATION FOR THREE PUBLIC UTILITIES READY TO GO ON THE LINE WITH A 30,000-KW. UNIT

ON THE TAUNTON River, just a few miles above the city of Fall River, Mass., there will soon be placed in operation a new electric generating station—a super-power station of the most modern design. It will be known as the Somerset Station of the Montaup Electric Co. The early completion of this station will mark another step towards the realization of centralized power generation as endorsed by the Department of Commerce, and while New England already has several super-power plants, the Somerset Station has the distinction of being the first instance in which several independent public utilities have united under a co-operative plan for the purpose of jointly constructing and operating a modern base load steam generating station. The plant was designed and constructed by Stone & Webster, Inc., of Boston.

The Montaup Electric Co. was organized by three public utility corporations, the Fall River Electric Light Co., the Blackstone Valley Gas & Electric Co. of Pawtucket, R. I., and the Edison Electric Illuminating Co. of Brockton, Mass., all of whom are now operating efficient steam generating stations. These stations will continue to carry the daily peak loads of their respective companies while Somerset Station will carry the combined base load by the associated companies.

Transmission of power from the new station to the load dispatching centers of the companies it serves is effected at the present time by 66,000-v. lines, which are, however, designed for future operation at 115,000 v. The component companies will not only derive all of the benefits of interconnection, since the new lines will permit the shifting of the load from one plant to others in emergency, but will also procure a considerable portion of their respective power requirements at a rate corresponding to large scale base load operation.

General Features of the Station

The station is located at Somerset, Mass., on the west bank of the Taunton River. The property has a river frontage of 1750 ft. extending approximately north and south and is divided into two parts by Riverside Avenue which is the main traffic artery from Fall River to the north. The power plant buildings and the outdoor switching equipment is located between the avenue and the river and the oil storage tanks and water reservoir on the opposite side of the road. The total area of both pieces of property is almost 45 acres, providing ample area to accommodate an ultimate station development of 200,000-kw. ultimate capacity.

The initial installation consists of one 32,000-kw. turbo-generator unit with three 1492-hp. Stirling boilers although the building is large enough to accommodate six boilers and two turbine units. All the main buildings are of steel frame construction resting on concrete foundations with brick walls, concrete floors, metal sash and concrete roof. The main operating floors in the turbine room are finished with red quarry tile. In the control room, the concrete floor is overlaid with cork linoleum. In general, all other floors have a granolithic finish. In the construction of this plant little excavating was necessary to reach suitable foundations because of the solid rock formation underlying the property.

Oil is used as fuel at the present time but provisions have been made throughout the design of the boiler plant so that pulverized coal can be burned whenever it becomes desirable in the future. A steam pressure of 375 lb. per

sq. in. and a total temperature of 700 deg. have been adopted.

In laying out this station, the turbine room, as may be noted from the accompanying drawings, was located adjacent to the river so as to make the circulating water tunnels as short as possible, and to avoid excessive rock excavation. The boiler plant adjoins the west wall of the turbine room and the switchhouse forms the westerly building of the station. To the west of the switchhouse the transformer repair shop and the outside switching and transformer equipment is located. A five-story office building, 24 by 60 ft., forms the southerly portion of the power plant building. A passenger elevator is installed in the boiler room adjacent to the office bay for general service to all floors in the office bay and boiler room. To the south of the power plant, a large area has been reserved for the future pulverized coal preparation plant and for coal storage. A wharf 404 ft. long constructed of precast concrete blocks will be provided for general docking purposes, the wall construction being such as to give a channel depth of 35 ft. at mean low water level.

The Boilers

Each of the three Stirling boilers included in the initial installation are built for a working pressure of 400 lb. and have a heating surface of 14,916 sq. ft. They are provided with convection type superheaters located between the front and middle banks of tubes designed to give 264 deg. F. superheat with 375 lb. steam pressure when the boilers are operating at 200 per cent of rating. The boilers are set with the center line of the lower drum about 13 ft. above the boiler room floor. They are supported upon cast-iron saddles bolted to structural steel beams which are framed into the building columns. The supporting saddles at one end of each drum will be equipped with roller bearings to permit longitudinal expansion of the drums during operation. Each boiler will be equipped with a single-pass steel tube economizer having a heating surface of 9220 sq. ft. One boiler has also been equipped with a steel tube type air preheater and the design is such that additional air preheaters can readily be added to the other boilers, if desirable in the future.

Draft for Combustion

Both forced and induced draft is used. The forced draft systems consist of two, 30,000-c.f.m. fans for each boiler, each fan being driven by a 40-hp. brush shifting motor having a speed range of 1048 to 1760 r.p.m. The induced draft system consists of one 110,000-c.f.m. multivane fan, direct connected to a 150-hp. brush shifting motor having a speed range of 252 to 814 r.p.m.

Both the induced draft and forced draft fans are located on the fan floor over the boilers. The forced draft fan's location makes a simple connection to the air preheater inlet, and also has the advantage of enabling the air supply for the draft system to be taken direct from the outside of the building, through a louvred penthouse immediately above each forced draft fan.

The forced draft fan discharges the air downward through the two passes of the air preheater, thence through a duct system to the ventilated side and bridge walls of the boilers. The induced draft fans draw the flue gases from the boiler outlets through the economizers and the air preheaters to the fan and thence force them through a steel

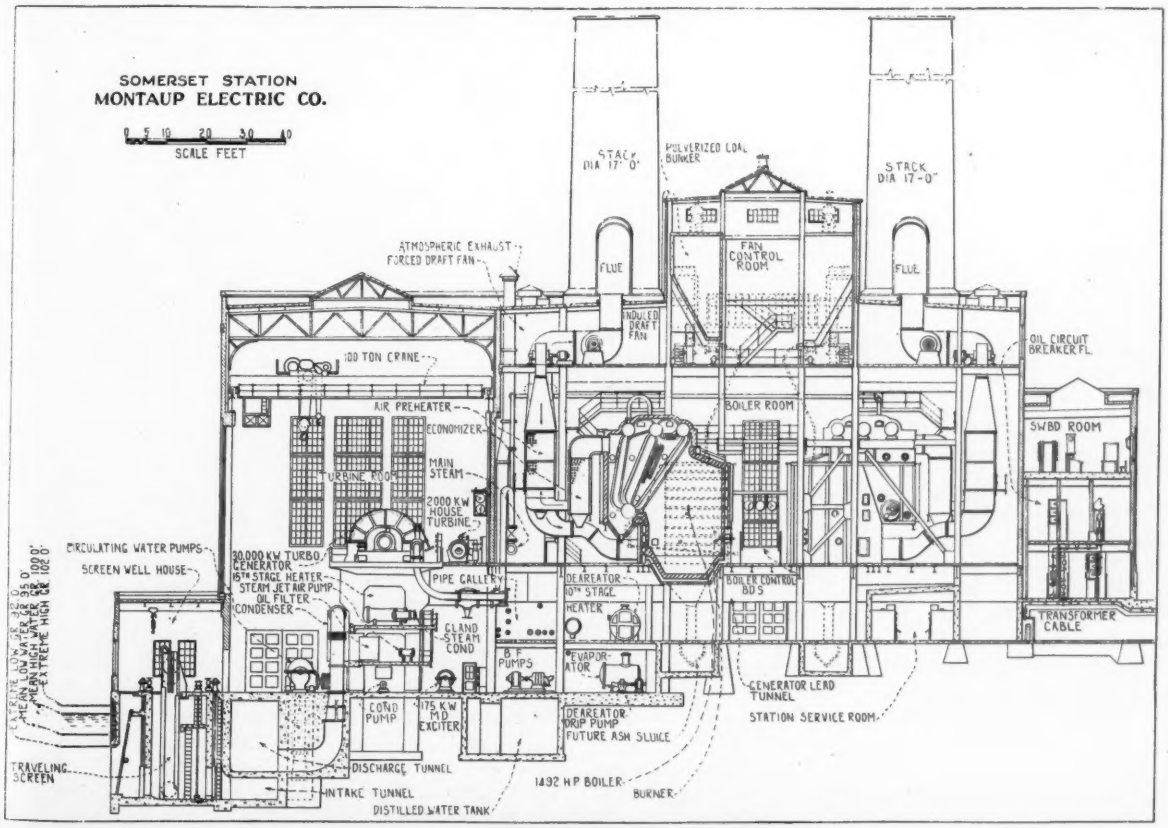


FIG. 1. ELEVATION THROUGH SOMERSET STATION

plate smoke flue which is carried on the roof of the boiler room to the stack. The stack is 17 ft. inside diameter and rises 200 ft. above the fan room floor grade at which the concrete stack mat is supported upon the structural steel framing of the boiler house. The total height of the stack above the firing floor is approximately 250 ft., the height being dictated by the future pulverized coal requirements rather than by those of the initial oil burning equipment.

boiler contains air-flow, steam-flow meters, flue gas temperature recorders and draft pressure gages, together with a signal light system to indicate whether the fans are running or idle.

Furnace Construction

In order to provide proper conditions for the future use of pulverized coal at high ratings, the furnaces have

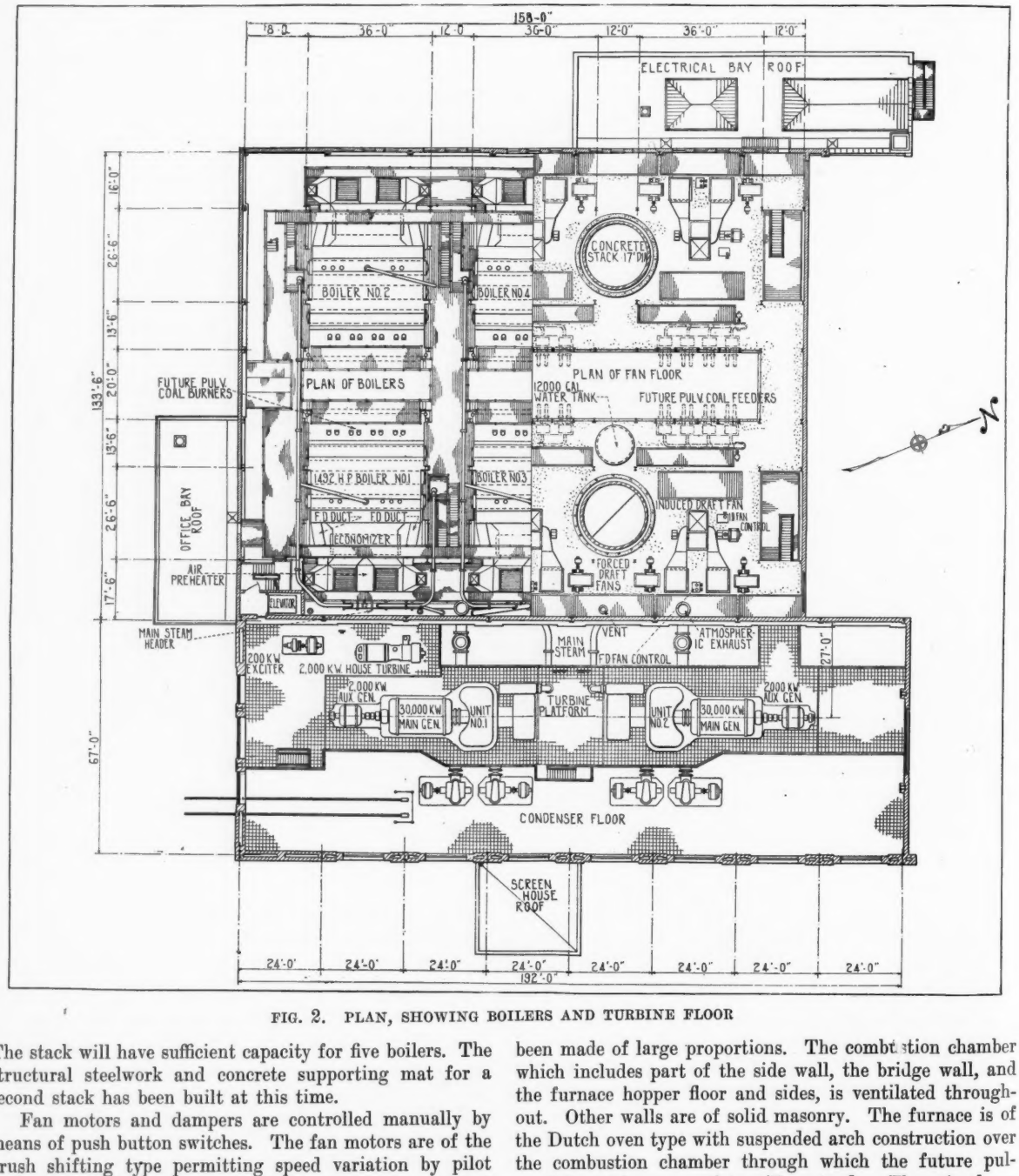


FIG. 2. PLAN, SHOWING BOILERS AND TURBINE FLOOR

The stack will have sufficient capacity for five boilers. The structural steelwork and concrete supporting mat for a second stack has been built at this time.

Fan motors and dampers are controlled manually by means of push button switches. The fan motors are of the brush shifting type permitting speed variation by pilot motors operated from remote control switches. One central control board is located in the firing aisle at each boiler and additional control equipment is provided adjacent to each motor on the fan floor. For assistance in operating the combustion control system, the control board for each

been made of large proportions. The combustion chamber which includes part of the side wall, the bridge wall, and the furnace hopper floor and sides, is ventilated throughout. Other walls are of solid masonry. The furnace is of the Dutch oven type with suspended arch construction over the combustion chamber through which the future pulverzied coal burner outlets will protrude. There is also a suspended arch over the last pass.

Forced draft fans discharge the air for combustion to two distributing ducts one at each side of the rear of the setting. Each duct supplies air to the bridge wall and to

the horizontal side wall air passages. The wall ventilation consists of horizontal air passages separated by bonding tile, and extending from the vertical distributing steel duct through the side and front walls. In the front wall several of the bonding tile are omitted from the horizontal rows above the burner box, thus allowing the air from the upper passages to flow downward into the burner box. The air passages in the bridge wall are arranged in a manner generally similar to those of the front wall. From the bridge wall the air passes into a system of tile ducts extending under and around the sides of the furnace floor. These ducts terminate in cast-iron boxes which support the bridge wall and the front wall, forming a series of openings under these walls. Adjustment of air distribution to the various ventilating passages is effected by means of dampers in the main ducts and in the individual wall passages. Thermometers are installed to show the relative cooling effected over different parts of the furnace walls and the dampers may be adjusted to give the same temperature in each of the ducts.

Since the wall ventilating spaces are subjected to a pressure of 1½ in. under normal operating conditions, the walls are designed to support this pressure. Protection against damage from higher pressure is afforded by the provision of automatic relief doors. Special holding and supporting tiles are set in the furnace wall. These extend across the air space to the face of 4 in. H-beams which run horizontally around the furnace. The tiles are bonded to the beams by specially designed malleable iron hooks one end of which is inserted in a hole in the tile, the other end resting over the flange of the H-beam. In this manner the 9-in. furnace wall is anchored to the H-beams allowing very little play for inward or outward movement but ample allowance for horizontal or vertical expansion of the wall.

In construction, the bridge wall is substantially the same as that of the furnace walls, differing only in that the tile are longer in order to span a wider air space. This wider air space is necessary in the bridge wall because all of the air flowing under the furnace hopper must first pass through the bridge wall, which actually serves as a plenum chamber for the distribution of air to the various furnace hopper ducts. Holding and bonding tiles are also used in the solid brick sections of the side and rear walls. Four courses are used, spaced about 4 ft. apart at the grades of the corresponding courses in the ventilated walls. Beams for holding hooks are also installed adjacent to the tile courses.

Where separation of walls occurs and difference of expansion is to be expected, the opposite surfaces of the walls, whether abutting or parallel are particularly smooth and true so that there may be no undue strains if the walls come in contact. The brick adjoining such a separation space are laid up solidly against a sheet metal strip of the required thickness, which is later removed. The higher temperature and consequently greater expansion of the furnace walls, even though ventilated, requires that there be no form of rigid bond between them and the walls at a lower temperature adjacent to them. The ventilated furnace walls are, therefore, built up independent of the other walls of the setting.

Air flowing through the ducts of the ventilated parts of the furnace walls will be under pressure and it is accordingly important that these walls be sealed at all points against leakage to the outside and, above the flame zone, against leakage into the furnace. Slight leakage into the flame zone of the furnace is not detrimental as the entering air may be used in combustion and compensated for by a reduction in quantity of air supplied through the burners.

Staggered expansion joints to take care of longitudinal expansion are located in the front, bridge, and side walls. They consist of a series of open joints ⅛ in. wide extending to the full height of wall in vertical lines at about 4 ft. 0 in. intervals.

Where these joints extend through the ventilating ducts, leakage of air into the furnace is prevented by covering the joint with strips of wire inserted asbestos. Where they cross the bonding tile, the seal is made by packing the joint with fire felt. The air ducts in the upper part of

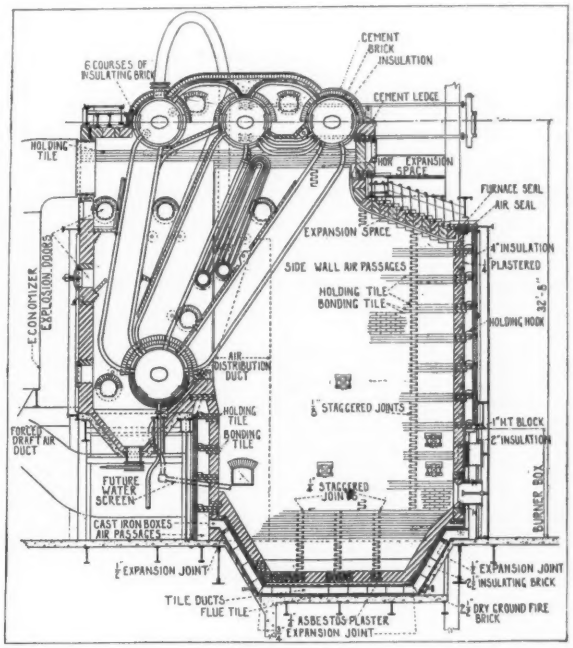


FIG. 3. THREE 1492-HP. BOILERS OF THIS TYPE HAVE BEEN INSTALLED

the setting are then lined with wire netting, and a plaster coat ¼ in. in thickness consisting of long asbestos fibre and high temperature cement is applied over the wire netting overlapping the edges of the asbestos strips to prevent air getting under them and through the expansion joints into the furnace. On the lower 12 ft. of wall, the edges of the asbestos fabric are sealed with a plaster strip. Slight air leakage through the strips into the furnace in the lower section is not objectionable.

Difference in vertical expansion between the part of the wall which is exposed to furnace temperatures and the wall area in the comparatively cool section protected by the tubes is taken care of by a vertical sliding joint opposite the bridge wall, extending upward to intersect with a 2½-in. horizontal expansion space located about 18 in. below the bottom of the steam drums. This vertical sliding joint is ¼ in. wide and is closed on the outside by a 12-in. strip of $\frac{1}{16}$-in. asbestos folded lengthwise, the folded edge inserted into the ¼-in. space about 4 in., the free edges bent over in opposite directions and pasted to the wall with sodium silicate. The space between the fold is caulked

with asbestos wicking. The 2½-in. space is closed on the outside by a 9-in. curtain wall built upon a steel bracket attached to the buckstays. A sliding joint is made between the inner and outer wall to allow the inner wall to travel up or down as occasioned by the expansion or contraction of the furnace wall.

To accommodate the end of the bridge wall, the side wall is recessed and a clearance of ⅛ in. is provided to insure for free expansion of bridge wall into this recess. A ½-in. space between the end of the bridge wall and the side wall to permit bridge wall expansion is packed with asbestos felt. At the two rear corners of the setting a ½-in. expansion joint is provided and two ½-in. "dovetail" expansion joints are located in the rear wall and in the upper front wall. The expansion space of these joints is packed with loose woven asbestos rope and wicking.

Expansion in the brickwork of all four sides of the furnace hopper is permitted by ¼-in. "staggered" expansion joints, spaced about 3 ft. apart and by a ¾-in. expansion space extending completely around the brick floor of the hopper.

At the top of the front wall and side walls, opposite the suspension arch, special irregular shaped tile properly recessed for the accommodation of packing are used. These tile provide for a 2-in. upward movement of vertical walls and about a 1-in. outward movement of arch. The upper part of the tile is shaped to form a 2½-in. pocket between the end of the arch and the inside face of the tile. This pocket extends around the outside face of the suspension arch and is packed with asbestos roll felt packing and asbestos wicking. A 2-in. pocket formed by a 6-in. channel is provided at the back of the tile, packed with similar material to prevent air leakage through the top of the ventilated wall passages. A wall of insulating brick 4 in. in thickness forms the outer side of the air ducts and also serves as an insulator for the outer casing of the boiler setting.

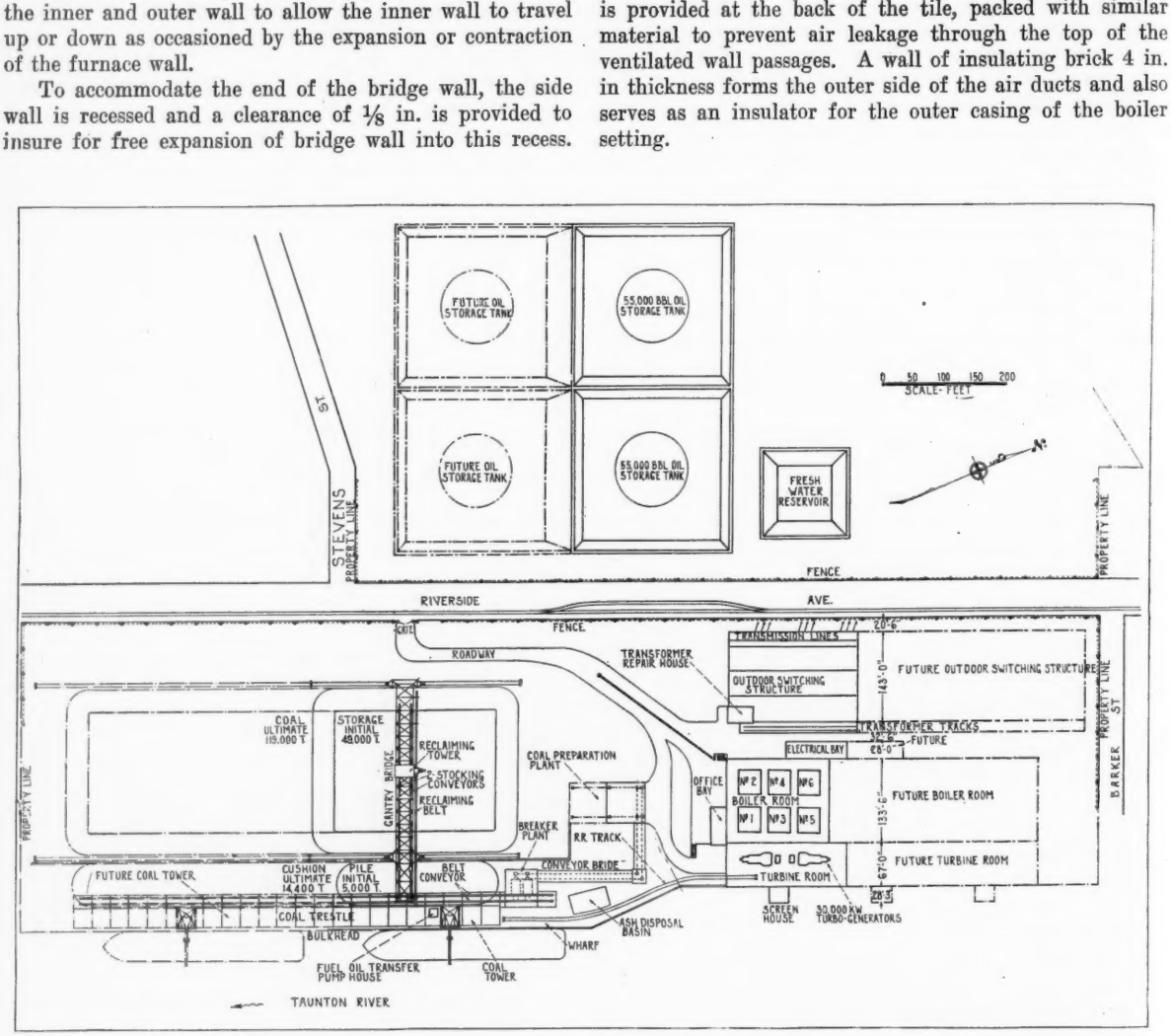


FIG. 4. PROPERTY PLAN, SHOWING RELATIVE LOCATION OF BUILDINGS AND FUEL STORAGE

Ventilating passages in the side and front walls are encased with $\frac{3}{16}$-in. steel plate bolted to the buckstay system. The back of the bridge wall is also enclosed in a $\frac{3}{16}$-in. steel casing, forming a protection for the 4-in. insulating brick wall.

Fuel

For the present installation two fuel oil storage tanks of 55,000 bbl. each are provided and space has been reserved for the future erection of two additional tanks of the same size. The oil is delivered in tank steamers and is pumped directly into the storage tanks. From the latter it flows by gravity to the 1200-bbl. concrete service tanks located beneath the oil pump room floor. Two 60-gal. and one 30-gal. motor-driven rotary pumps and one 30-gal. steam-driven rotary pump, are installed for delivering the fuel oil to the burners. The steam-driven unit is provided for emergency service. These units will discharge the oil at approximately 275 lb. pressure, through a straight tube heater which will raise its temperature to approximately

275 deg. F. Suitable oil strainers and meters to measure the oil delivered to the boilers are provided.

Fresh Water Supply and Feed Water Equipment

Fresh raw water for the entire station will be obtained from the Coles River which is located about three and one-half miles from the station. An 8-in. pipe line will bring the water from the river pump house to the 1,000,000-gal. reservoir at the station. The water will be distributed in the station by two 150-gal. and one 800-gal. centrifugal pumps. For normal operation one 150-gal. pump will be large enough to supply the station needs, while the 800-gal. pump will carry the entire capacity of the station in the event of having to discharge the condensate overboard.

All water used for boiler feed make-up will be provided by evaporators and the entire boiler feed supply will be passed through a deaerator which will remove air and gases which would cause corrosion in the boilers and economizers. Raw water will be used for boiler feed purposes only under emergency conditions. The condensate from the main condenser is pumped through the turbo-generator oil cooler into the condensate line and the surge tank, passing through the 15th stage extraction heater and through a gland steam heater into the deaerator. The deaerator pump removes the water after deaeration and discharges it through the 10th stage heater (which also serves as an evaporator condenser when the evaporator is operating) to the boiler feed suction header; from this header the boiler feed pumps discharge the water through the economizers into the boilers. Boiler feed make-up is taken from the distilled water storage tanks which have a total capacity of 300,000 gal. and is pumped to the surge tank where it mixes with the condensate from the main condenser. The distilled water make-up supply pumps are operated automatically by float switches in the surge tank.

The deaerator is a combination deaerator and stage heater, which takes its normal supply of steam from the 12th stage of the main turbine. Steam for the deaerator is also taken from the exhaust steam header automatically through an "unloading valve." During the building heating season it is planned to run some of the steam auxiliaries and to use the exhaust steam for heating service. If more steam is available than is required for heating, the "unloading valve" will bleed the excess to the deaerator, automatically reducing the flow from the 12th stage extraction outlet a corresponding amount.

Generating Equipment

The turbo-generator unit, installed, consists of a steam turbine, a 30,000-kw. generator, a 2000-kw. auxiliary generator and an exciter for the auxiliary generator all on the same shaft. Surface type air coolers cool the air from the main and auxiliary generators, the cooling system being entirely enclosed and the air recirculated continuously through the generator and cooling chamber. River water is used as the cooling medium.

A 45,000-sq. ft. surface condenser has been provided to condense the steam from the main turbine. Two circulating water pumps each having a capacity of 40,000 g.p.m. when operating alone and having a combined capacity of 60,000 g.p.m. will supply the condenser cooling water. The water for these pumps will pass through a traveling water screen. The other condenser auxiliaries include two 660-g.p.m. motor-driven centrifugal hot-well pumps and two steam jet air pumps with surface inter and after coolers, designed for normal operation with condensate as a cooling medium.

Details of the Electrical Equipment

All of the station auxiliaries used in the normal operation of the plant will be driven by alternating current motors. Motors of 25 hp. and less will be on 550-v. service. Speed regulation is obtained through the use of brush shifting and slip-ring motors. All constant speed motors above 15 hp. are of the double squirrel cage type, thus eliminating entirely the use of starting compensators.

Power for all the auxiliaries upon which the continuity of operation of each main unit depends will be furnished from the auxiliary generator which operates in synchronism with its main generator. In starting a main unit, all of its auxiliaries will be started from the station service bus which will be fed through station service transformers from the 14,000-v. transfer bus. After the unit is in operation the important auxiliaries will be transferred to the auxiliary 2300-v. and 550-v. busses of that unit, and thus be supplied from the auxiliary generator independently of the station service busses. The less important unit auxiliaries, and also those station auxiliaries which are not intimately

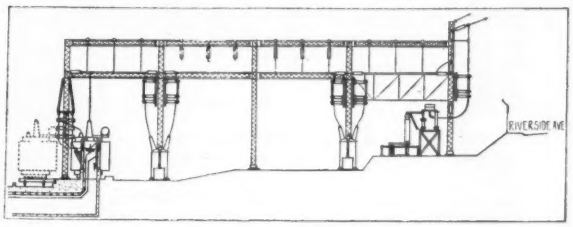


FIG. 5. HIGH TENSION SWITCH STRUCTURE

connected with the operation of any one unit, will be operated from the station service busses.

Each main generator is normally excited by a 175-kw. motor generator set, consisting of a 2300-v. induction motor and a 250-v. direct-current generator. This set will be operated normally from the auxiliary unit bus, but on failure of voltage on that bus, it will be automatically connected to the station service bus. Each auxiliary generator is normally excited by a direct-connected exciter, but provision is made for excitation from the emergency excitation bus. Automatic voltage regulation of the auxiliary generator and its exciter is also included. A spare steam-driven exciter will be used at present for furnishing emergency excitation, supplemented by a motor-driven exciter in the future.

Arrangement of Switching Equipment

All generator and transformer cable leads are carried in tunnels terminating in the basement of the electrical bay and where space is also provided for generator or feeder reactors should they be required in the future. The 14,000-v. generator bus and the instrument transformers are located on the first floor of the electrical bay.

Longitudinal cross partition walls separate these transformer compartments from the bus. On the second floor the 14,000-v. transfer or auxiliary bus and the oil circuit breaker and disconnecting switch equipment is located, the bus being separated from the switching equipment by partition walls. All partition walls, barriers, and circuit breaker cells are constructed of repressed brick. The main switchboard and control bench is located on the third floor, which also accommodates the load dispatcher's room.

Equipment in Somerset Station of the Montaup Electric Co.

General

Location ..... Somerset, Mass.
Character of service .....
Serving scattered communities over high tension transmission lines.
Capacity, present building ..... 60,000 kw. at 80% P. F.
Capacity, Ultimate ..... 210,000 kw.
Designed and built by ..... Stone & Webster, Inc.

Boilers and Superheaters

Manufacturer ..... Babcock & Wilcox Co.
Type of boiler ..... Stirling Class 13
Heating surface, per boiler ..... 14,920 sq. ft.
Furnace volume ..... 12,900 cu. ft.
Furnace volume, per sq. ft. heating surface ..... .865
Type of superheater ..... B. & W. convection type
Superheating surface, per boiler ..... 4060 sq. ft.
Sq. ft. superheating surface, per boiler heating surface. .265
Steam Temperature .....
.....700 deg. F. at 200% rating with 14% CO_2
Corresponding superheat ..... 258 deg. F.
Economizers ..... Power Specialty Co.
Type ..... Foster
Heating surface, per economizer 9288
Economizer surface, per sq. ft. boiler heating surface ... 0.62

Fuel

Kind (present) ..... Oil
Heat value B.t.u., per lb 19,000
Kind (future) ..... Bituminous, in pulverized form

Air Preheater

Manufacturer ..... Babcock & Wilcox Co.
Type ..... Tubular
Heating surface ..... 10,712 sq. ft. per boiler
Preheater surface, per sq. ft boiler heating surface ... 0.718
Diameter of tubes ..... 2½ in.
Free area for gas ..... 6.08 sq. in. for rated hp.
Free area for air ..... 2.3 sq. in. for rated hp.

Boiler Settings

Distances:
Floor to center line mud drum ..... 13 ft. 0 in.
Floor to center line steam drum ..... 32 ft. 8 in.
Front wall to bridge wall ..... 18 ft. 4¾ in.
Furnace width ..... 29 ft. 0 in.
Front and rear suspended arches ..... Bigelow Arch Co.
Fire brick, 1st quality:
53,000 Benson brick ..... Big Savage Fire Brick Co.
72,000 "Mizzou" brick and 14,000 tile .....
..... A. P. Green Fire Brick Co.
Fire brick, 2nd quality:
62,000 "Elk" brick ..... Elk Fire Brick Co.
Insulating brick—33,000 .. Armstrong Cork & Insulation Co.

Miscellaneous Boiler Fittings

Safety valves ..... Consolidated 4—4½ in.
Blow-off cocks ..... Everlasting 3—2½ in.
Blow-off valves ..... Yarway type "B" 3—2½ in.
Soot blowers ..... Diamond Valv-in-Head—16 per boiler
Gage glasses ..... Ernst—Inclined type
Water columns ..... "Stets"
Feed water regulator ..... "Stets"

Chimney

Type ..... Reinforced concrete supported on building steel
Built by ..... Heine Chimney Co.
Diameter ..... 17 ft. 0 in.
Height, above boiler room floor ..... 250 ft. 0 in.

Oil Storage

Storage ..... 2—55,000 bbl. tanks
Maker ..... Chicago Bridge & Iron Works
Service tanks, number 2
Capacity ..... 1200 bbl. each
Materials ..... Concrete

Oil Burning Equipment

Fuel Oil Pumps—
Maker ..... W. E. Quimby, Inc.
Type ..... Rotary
Fuel Oil Heaters—
Maker ..... Whitlock Coil Pipe Co.
Temperature, oil ..... 275 deg. F.
Pressure, oil ..... 275 lb.
Oil Burners—
Maker ..... Babcock & Wilcox Co.
Type ..... "Lodi" mechanical atomizing
Number, per boiler 12
Normal capacity ..... 900 lb. oil per burner per hr.
Maximum capacity ..... 1200 lb. oil per burner per hr.

Forced Draft Fans

Maker ..... B. F. Sturtevant Co.
Type ..... No. 80 special design 5, turbovane
Driven by .....
..40 hp., 2200 v., B. T. S. motors—General Electric Co.
Capacity, each ..... 30,000 c.f.m. at 5 in. water pressure

Induced Draft Fans

Maker ..... B. F. Sturtevant Co.
Type ..... No. 110 design 2 type S. S. V.
Capacity, each ..... 110,000 c.f.m. at 5½ in. water
Driven by .....
..150 hp., 2200 v., B. T. S. motors, General Electric Co.

Boiler Feed Pumps

Makers .....
Worthington Pump & Machinery Corp., Jeanesville and Ingersoll-Rand Co., Cameron.
Number ..... 3—Jeanesville, 1—Cameron
Capacity, g.p.m. ..... 2—800, 1—800, 1—500
Discharge head ..... 440 lb. per sq. in.
Driven by (800 g.p.m.) .....
.....300 hp., 2200 v. motors, General Electric Co.
(500 g.p.m.) .....
.....180 hp., 350 lb. pressure, Westinghouse turbine

Deaerator Pumps

Maker ..... Worthington Pump & Machinery Corp.
Capacity, each ..... 800 g.p.m.
Driven by ..... 60 hp., 2300 v., G. E. induction motor

Extraction Heaters

Makers ..... Cochrane Corp.
Type ..... Four-pass, floating head, closed type

HEATERS

	15th Stage	Gland Steam	10th Stage
Surface, sq. ft.	1025	216	1320
Water, per hr.	286,300 lb.	300,000 lb.	356,800 lb.
Temp., entering	100 deg. F.	146 deg. F.	236 deg. F.
Temperature, leaving	146 deg. F.	163 deg. F.	286 deg. F.
Abs. pressure	3.9 lb.	14.7 lb.	44.6 lb.

Turbo Generator

Maker ..... General Electric Co.
Type ..... Single cylinder, axial flow, impulse
Capacity .....
Turbine 32,000 kw. main generator, 30,000 kw. (37,500 kv.a.) auxiliary generator 2000 kw. (2500 kv.a.)
Speed ..... 1800 r.p.m.

Surface Condenser

Maker ..... Wheeler Condenser & Engineering Co.
Type ..... Two-pass, two compartment bowl shaped
Tube surface ..... 45,000 sq. ft.
Tube surface, per kw. generator rating 1.41
Lb. steam, per sq. ft. per hr. (No bleeding) 7
Tubes, composition ..... Admiralty, by cupping process
Tube maker ..... Scovill Mfg. Co.

Circulating Water Pumps

Number ..... 2 per condenser (Wheeler C. & E. Co.)
Capacity, one pump running ..... 40,000 g.p.m.
Capacity, two pumps running ..... 60,000 g.p.m.
Driven by .. 250 hp., 2300 v., variable speed induction motors

Condensate Pumps

Number ..... 2 per condenser (Wheeler C. & E. Co.)
Capacity, each ..... .660 g.p.m. (330,000 lb. per hr)
Driven by ..... 50 hp., constant speed motors

Air Removal Equipment

Number ..... 2 units per condenser (Wheeler C. & E. Co.)
Type .... Steam jet with surface inter- and after-condenser

Equipment in Somerset Station of the Montaup Electric Co.—Continued

Number of elements....2 per unit
Capacity, per unit....178 lb. air per hr. at 70 deg. F.

Generator Air Coolers

Maker....General Electric Co.
Type....Surface

Deaerator

Maker....Elliott Co.
Steam pressure....
11 to 26 lb. abs. (extracted from 12th stage of turbine or from auxiliary exhaust)
Capacity (lb. per hr)....357,000 (max.) 303,000 normal
Water temperature...165 deg. F. inlet to 222 deg. F. outlet
Steam required, per hr. lb....17,300 normal

Evaporator

Maker....Griscom-Russell Co.
Type....Two effect, high heat level
Steam taken from....7th stage of main turbine

Exciters

Motor-Driven—
Maker....General Electric Co.
Capacity....175 kw.
Voltage....Motor 2300 a.c., generator 250 d.c.
Turbine-Driven—
Maker, turbine....Terry Steam Turbine Co.
Maker, generator....General Electric Co.
Capacity....200 kw.

Cranes and Elevators

Turbine room crane....Niles-Bement-Pond Co.
Capacity (tons)....Main hoist 100, auxiliary hoist 15
Transformer repair house crane....Whiting Corp.
Capacity (tons)....30
Service elevator....Otis Elevator Co.
Capacity....3000

Screen Well Equipment

Water screens....Chain Belt Co.
Type....“Rex” traveling
Sluice gates....Coffin Valve Co.
Screen pumps....DeLaval Steam Turbine Co.
Screen well drain pump..Worthington Pump & Mchy. Corp.
Type .4 in. vertical, single suction, single stage, centrifugal

Miscellaneous Pumps

Service pumps....DeLaval Steam Turbine Co.
Type....Double suction, single stage, centrifugal
Number....1 2
Capacity....800 150

Generator air coolers pumps...DeLaval Steam Turbine Co.
Type....Double suction, single stage, centrifugal
Capacity (each) g.p.m....800

Transformer oil pumps....DeLaval Steam Turbine Co.
Type....Double suction, single stage, centrifugal
Capacity (each) g.p.m....250
Driven by....
....15 hp., 550 v., constant speed, G. E. induction motor

Distilled water pumps....
....Worthington Pump & Machinery Corp.
Type....6 in. vertical, single suction, two-stage, centrifugal
Capacity (each) g.p.m....800
Driven by....40 hp., 2300 v., G. E. induction motor

Sump pumps....Worthington Pump & Machinery Corp.
Type..2 in. vertical, single suction, single stage, centrifugal
Driven by....3 hp., 550 v., G. E. induction motor

Evap. feed pumps..Worthington Pump & Machinery Corp.
Type....2 in., single suction, two-stage, centrifugal
Used for....Feeding raw water to evaporator at 200 deg. F.
Capacity (each) g.p.m....50
Discharging head (ft.)....200
Driven by....10 hp., 550 v., G. E. induction motors

Deaerator drip pumps...Worthington Pump & Mchy. Corp.
Type....2 in., single suction, two-stage, centrifugal
Used for....
Removing drips from deaerator coils, and discharging into deaerator supply at 230 deg. F.
Capacity (each) g.p.m....60
Driven by....7½ hp., 550 v., G. E. induction motor

Drip pumps for extraction heaters....
....Worthington Pump & Machinery Corp.
Type....2 in., single suction, two-stage, centrifugal
Fire pump....DeLaval Steam Turbine Co.
Type....
10 in., double suction, single stage, centrifugal, turbine driven.
Capacity, g.p.m....1500

Tanks

Raw Fresh Water (Surge)—
Capacity (gal.)....14,000
Made by....Coatesville Boiler Works
Distilled Water (Surge)—
Capacity (gal.)....10,000
Made by....Coatesville Boiler Works
Distilled Water Storage—
Two concrete tanks under condenser floor total capacity....330,000 gal.
Raw Fresh Water Storage—
One concrete reservoir capacity....1,000,000 gal.

Miscellaneous Equipment and Materials

Building steel (2200 T.)....American Bridge Co.
Skylights and louvres....E. Van Noorden Co.
Stairways and walkways....Babcock Davis Corp.
Subway grating....Klemp Co.
Roofing....J. T. McGuire
Ventilators....E. Van Norden Co.
Circulating water piping....Lumsden & Van Stone Co.
Circulating water valves....
....Pittsburgh Valve, Foundry & Construction Co.
Circulating water expansion joints....U. S. Rubber Co.
Air compressor....Worthington Pump & Machinery Corp.
Lubricating Oil System—
Oil coolers....Schutte & Koerting Co.
Filters....
S. F. Bowser & Co. and DeLaval Steam Turbine Co.
Feed pump regulator....Ruggles-Klingemann Co.
Feed pump control....General Electric Co.
Desuperheaters....Elliott Co.
High Pressure Steam System—
Gate valves....Pittsburgh Valve, Fdry. & Constr. Co.
Globe valves....Edward Valve & Mfg. Co.
Boiler non-return valves....Schutte & Koerting Co.
Pipe....Pittsburgh Valve, Fdry. & Constr. Co.
Fittings....Lumsden & Van Stone Co.
Holly drip system....Russell B. Hobson
Low Pressure Steam and Water Systems—
Gate valves....Reading Valve & Fittings Co.
Check valves....Reading Valve & Fittings Co.
Pipe and fittings....
Grinnell Co., Power Piping Co., Pittsburgh Piping Equipment Co.
Copper expansion joints....E. B. Badger & Sons Co.
Atmospheric Relief System—
Valve....Atwood & Morrill Co.
Pipe....Lumsden & Van Stone Co.
Spiral riveted pipe....American Spiral Pipe Works

Combustion Control System

Maker....Bailey Meter Co.
Type....Manual, arranged for future change to automatic
Panel boards....One for each boiler
Instruments....
On each panel board; 1—Bailey boiler meter; 1—4 pin temperature recorder for economizer; 1—4 pen temperature recorder for air preheater; 1—Bailey multi-pointer draft gage.

Instruments

Venturi meter....Simplex Valve & Meter Co.
Thermometers—
Indicating....Schaeffer & Budenberg Mfg. Co.
Recording....The Foxboro Co., Inc.
Steam Flow Meters....Bailey Meter Co.
Gages—
Indicating....Ashcroft Mfg. Co.
Recording....The Foxboro Co., Inc.
Draft....Bailey Meter Co.
Fuel oil meter....Bassler Meter Co.
Load indicators....Payne Dean Ltd.

Each generator is connected through an oil circuit breaker to its individual bus, which in its turn is connected to a transfer bus through a bus tie oil circuit breaker. The generator leads are carried in tunnels from the turbine room through the boiler room to the basement of the electrical bay. From each generator bus a 37,500-kv.a. step-up transformer circuit is taken through underground tunnels to the outdoor switchyard and there connected through

For auxiliary power there will be installed ultimately three 3000-kv.a. transformer banks each feeding a section of 2300-v. station service bus from which will be taken feeders for the 2300-v. station auxiliaries, the 550-v. power transformers, and the station lighting transformers. The capacity of these 3000-kv.a. banks will be such that any two will carry the entire station load and the starting load of the auxiliaries for two turbo-generator units.

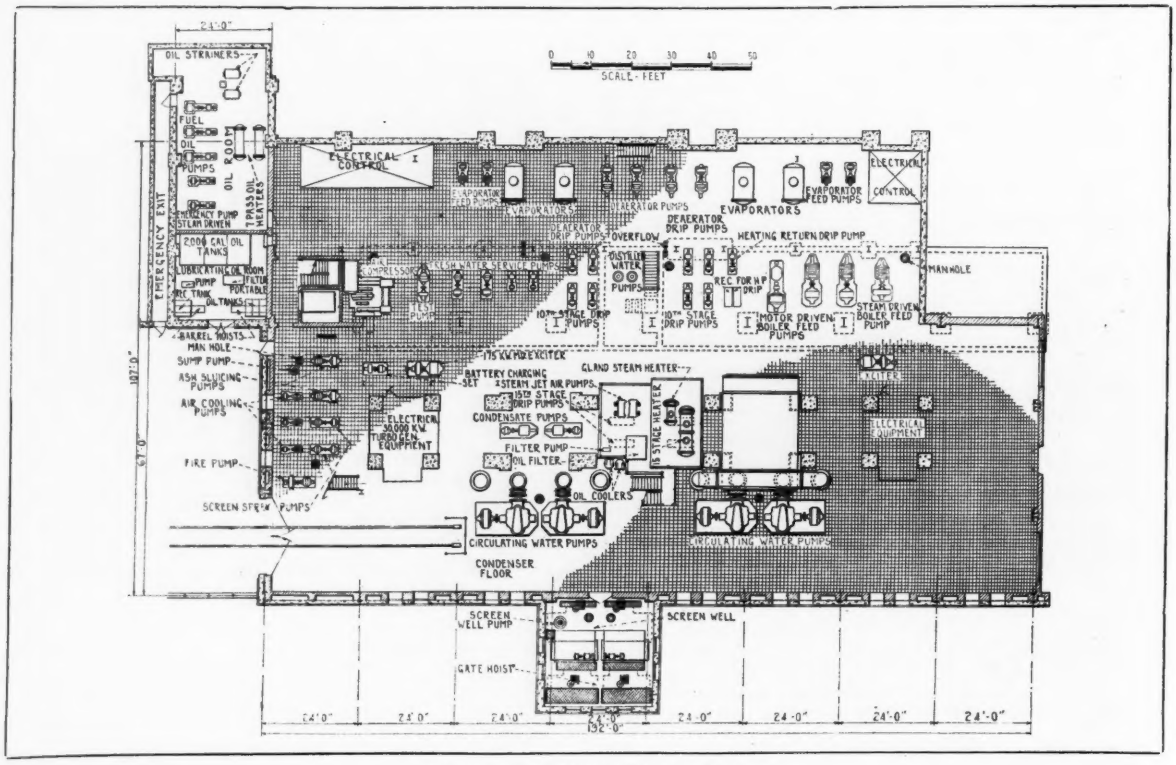


FIG. 6. THE CONDENSER FLOOR

selector oil circuit breakers to the two outdoor high tension busses. The 14,000-v. transfer bus which is sectionalized in the middle will be used primarily for furnishing power, through station service transformers, to the station service busses, but is also available for transferring the load of a transformer circuit to any generator desired. The 14,000-v. oil circuit breakers are guaranteed to rupture 20,000 amp. at 15,000 v. The generators and their cable connections to the busses are protected by balanced relays which will automatically disconnect the generators from their busses should a short circuit develop or a ground occur on the generator side of the oil circuit breaker. Similar protection is arranged for the main transformers and their cable connections.

The initial high tension transmission system consists of three 66,000-v. lines, each connected ultimately through heavy duty oil circuit breakers to two high tension busses, although only one bus is installed with the first unit. All equipment installed, however, has sufficient insulation for conversion to 115,000-v. service in the future. Ultimately there will be eight 115,000-v. outgoing transmission lines from this station, all connected to the outdoor busses. The two high tension busses are sectionalized at the center by means of an oil circuit breaker. All the outdoor oil circuit breakers are guaranteed to rupture 7500 amp. at 132,000 v.

Prime Mover-Guards

Flywheels located so that any part is 6 ft. or less above floor or platform shall be guarded in one of the following ways:

(*a*) With an inclosure of sheet, perforated, or expanded metal or woven wire.

(*b*) With guard rails placed not less than 15 in. nor more than 20 in. from rim. When flywheel extends into pit or is within 12 in. of floor, a standard toe board shall also be provided.

(*c*) When the upper rim of flywheel protrudes through a working floor, it shall be entirely enclosed or surrounded by a guard rail and toe board.

(*d*) For flywheels with smooth rims 5 ft. or less in diameter, where the preceding methods cannot be applied, the following may be used: A disk attached to the flywheel in such manner as to cover the spokes of the wheel on the exposed side and present a smooth surface and edge, at the same time providing means for periodic inspection. An open space, not exceeding 4 in. in width, may be left between the outside edge of the disk and the rim of the wheel if desired, to facilitate turning the wheel over.—Safety Code for Mechanical Power Transmission Apparatus.

Factors Affecting Priming of Steam Boilers

Results of an Investigation to Determine Proper Operating Conditions in a Specific Boiler Plant. By C. E. Joos

WITH the increased demands placed upon steam boilers, under modern operating conditions, has come the necessity of giving further thought and study to the problem of priming. Few power plants are free from this problem; but, of course, large central stations, using low percentage of make-up water, are not troubled with priming to the extent that it occurs in plants operating under less ideal conditions.

Some misunderstanding exists as to the term "priming" and as the generally accepted usage is too broad for practical conception, it is thought best to draw a distinct line of demarcation between the terms priming and foaming. Generally speaking, foaming is a surface condition of water within a steaming unit, in which the steam space becomes filled—partially or totally—with bubbles or foam, due to a soapy or high alkaline condition of the concentrated water. Steam produced under this circumstance contains moisture, the amount depending upon the nature and quantity of foam within the steam drums. Naturally, such a condition is not indicated by the surging of water in the gage glass as commonly occurs in severe cases of priming.

Priming, on the other hand, is violent ebullition and usually indicates its presence by turbulent actions, in intermittent slugs of water passing over with the steam into the lines. Of the two, priming is the more common, in that operating conditions affect its intensity and while for our present purpose, we will discuss the subject of priming, in the sense as here described, attention is called to the fact that some detrimental conditions can exist as a result of foaming.

Investigation was conducted in a plant which had been troubled with priming for some time and various reasons with corrective measures were advanced. These measures failing to prove successful, the writer was requested to make a detailed investigation of the conditions at the particular plant, to point out the most salient factors governing the conditions and their possible relation to each other and to submit recommendations for correcting the trouble. Hence, as the reader will understand, this investigation was conducted under actual operating conditions with the usual demand for an uninterrupted power load.

The plant is well managed and operated, representing the average industrial plant of its size and one in which the condensate return for boiler feed purposes is negligible. The boiler water supply is from a large eastern river, whose mineral content, in terms of soluble salts is about the average industrial supply. This raw, or river water is passed through a hot process, continuous lime-soda ash softener, filtered and subsequently used for boiler feed purposes.

Inasmuch as the quality or purity of steam produced is so important to uninterrupted power service, it is obvious that it was the paramount factor in the investigation.

Two radically different methods were used for determining the quality of steam produced:

First, by the throttling calorimeter, a familiar method which may, thereafter, be passed without further comment.

Second, by a chemical method, substituting for a large number of calorimeters, that otherwise would have been required. This latter method is illustrated in Fig. 1 and as will be seen, the small circles represent steam traps which drain the various headers all along the boiler room. When priming occurs, it is reflected by the amount of water discharged into these traps as well as by its concentration or contamination of boiler water.

At the various observation periods, these trap discharges were collected and examined for their content of alkaline soda and sodium chloride—calculated in terms of percentage of boiler water concentration. Thus, a trap discharge water free of soda and salt would mean 100 per cent dry steam while those containing these materials indicated contamination proportionate to the percentage of boiler water contained in the trap discharge.

Readings of the trap discharges represent averages between each period of observation while the readings as to

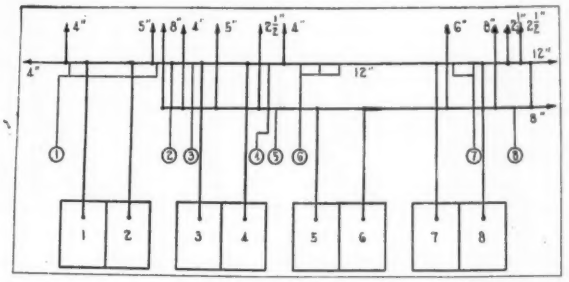


FIG. 1. LAYOUT OF BOILER PLANT SHOWING TRAPS THAT DRAIN STEAM HEADERS

rating, water level, etc., were taken at the end of each period. The observation periods were close enough to avoid any wide variation between readings, which of course, would affect the general conclusions of the tests.

The Fact

The investigation was divided into the variables that effect priming and in accordance therewith the following items were considered and will be discussed separately and in combination;

1. Character of load.
2. Concentration of total soluble salts in the boiler water.
3. Water level carried.
4. Type of boiler.

Character of Load

Two distinct phases of character of load will be noted, both of which effect priming. First, a condition in which the load is extremely variable and second, where the load is comparatively steady but high.

In order, therefore, to determine the effect of the first phase, a boiler was taken from 215 per cent rating to 60 per cent and, then back to 226 per cent all in a period of 10 min. That this is an important factor is shown by the sudden increase in moisture content to a value well above 5 per cent. See Fig. 2 and Table I.

Actual values of moisture content shown in Fig. 2 are probably higher than indicated inasmuch as 5 per cent moisture is about all that a calorimeter will record. The

figures, however, indicate the tendency and for our purpose, are more important than absolute value.

The second phase of load character was investigated by gradually raising the rating of the plant by cutting out units and subsequently raising the rating on the active boilers. In order to eliminate as far as possible the other variables that might influence results, the water level was carried steady and low while the concentration of total solids was 79 grains, on an average a figure well below the

TABLE I. TEST RESULTS TO SHOW EFFECTS OF RAPID CHANGES IN LOAD AND HIGH WATER ON PRIMING

Reading Taken in Intervals of Five (5) Minute Periods.

Observations	% Rating	Water Level	Moisture
1	228	4.5	4.80
2	194	4.25	4.50
3	178	6.00	2.90
4	215	6.00	5.25
5	60	5.50	5.20
6	226	6.00	3.75
7	187	5.50	2.75
8	178	5.50	2.70
9	180	5.50	2.70
10	184	5.50	2.70
11	194	5.75	5.00
12	196	4.50	4.80
13	185	5.00	3.50
14	196	5.50	2.80
15	195	6.50	2.70
16	194	7.50	2.70
17	194	9.00	5.50
18	175	10.00	5.55
19	183	10.50	5.55
20	165	9.50	5.55
21	186	8.00	5.55
22	205	6.25	5.65
23	185	6.00	4.50
24	165	7.00	2.75

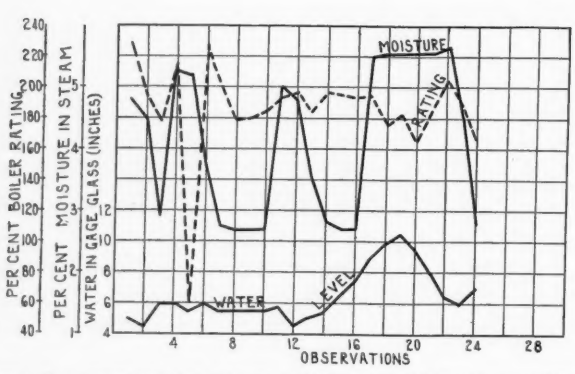


FIG. 2. EFFECTS OF RAPID CHANGE IN LOAD AND HIGH WATER ON PRIMING

normal operating figure of 200 grains and over. The intervals of time represent half hours, a sufficient time to eliminate the variable of rapid change in load.

Table II plotted in Fig. 3, represents the effects of rating above mentioned on priming at the concentrations carried. It will be noted from this data that the chemical method of determining steam contamination was used.

It is interesting at this point to note that the chemical test revealed an effect of priming, which is seldom considered. As indicated in Fig. 3, during the priming condition, the concentration of the boiler water was lowered which is shown by the lower alkalinity and salt reading, having much the same effect as that of blowing down a boiler. It may be of further interest to note that to get the factor of concentration low enough, it was necessary to blow down these boilers every hour during the night and every half hour during the day for the duration of the tests.

Concentration of Total Solids in Boiler Water

Perhaps the most important factor governing priming conditions is that of the total dissolved solids present within the boiler water. This is logical in that these solids add to the natural density and viscosity of pure water. At the beginning of the investigation, the boilers were in a priming condition, thus affording an opportunity to observe the effect of reducing concentrations rather than otherwise.

Reduction of concentrations is practically limited to two methods. First, relieving the boiler of the highly concentrated water by means of the blowoff valve and sec-

TABLE II. RESULTS OF TEST SHOWING EFFECT OF RATING ON PRIMING

Observation	Condensed Steam (Average) Gr. Soda	Gr. Salt	% Boiler cono.	Boiler Water Grains per Gal. Alkalinity	Salt	Per cent Boiler Rating
1	0.4	0.5	4.23	14.0	11.8	145
2	0.4	0.4	3.40			146
3	0.5	0.4	3.70	14.9	10.8	167
4	0.8	0.8	7.4			172
5	2.2	1.9	23.7	11.7	8.04	191
6	4.7	4.1	51.0			184
7	2.2	1.6	15.2	14.5	10.5	148
8	2.0	1.6	14.8			160
9	0.8	0.6	5.5	14.5	10.8	154

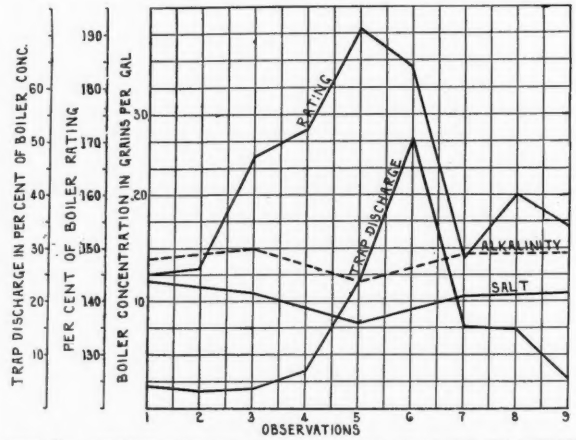


FIG. 3. EFFECT OF HIGH RATINGS ON QUALITY OF STEAM

ond, by chemically precipitating the predominating salts that make up the solids present in the boiler water. Both of these methods will be discussed separately.

In order to observe the effect of blowing down and consequent reduction of concentration on priming, two boilers were used for the purpose. Blowdowns were increased gradually and close observation was made for the effect on the concentration of the boiler water and that of the condensed steam.

During the entire investigation, the ratings were kept as nearly constant as possible, which was easily accomplished as the boilers are oil fired.

No doubt as to the effect of blowdowns can exist, as indicated by the data as shown in Table III and as plotted in Fig. 4. Starting with a schedule of blowing down every 3 hr. and gradually increasing the blows to every half hour, the contamination of boiler water in condensed steam was reduced from 66.6 per cent to 9.1 per cent.

While the total solids of the boiler water were not determined chemically in any case, during this investigation, the amount of salt or sodium chloride is a good indication

of their amounts and, incidentally, may be calculated from the readings by the aid of a factor which was determined from an analysis.

This factor was derived by analyzing the boiler water for total solids, salt and alkalinity in terms of grains per gallon. The alkalinity is subtracted from the total solids and the remainder divided by the salt reading. To illustrate with the following readings:

Akalinity	Salt	Total Solids
28.5	29.0	280

The factor is obtained as follows:

$$(280 - 28.5) \div 29.0 = 8.67$$

Inasmuch as the water in question is from a large stream, the relative chemical composition remains the same over short intervals.

In the foregoing test, therefore, taking the first reading and using the factor as derived above the total solids would be calculated by reversing the above procedure which is as follows:

Alkalinity (Soda)	Sodium Chloride (Salt)	Factor
28.3	16.8	8.67

$$(16.8 \times 8.67) - 28.3 = 145.6$$

In order to prove conclusively the value of low concentrations, one of the boiler units was tested just after being in service 24 hr. In this space of time, the concentrations built up to 64.4 grains per gallon; by eliminating the blowdowns, they increased to 122.0 grains per gallon at the end of 17 hr.

During the first part of the test, the rating of the boiler under test was purposely increased from 128 per cent to 188 per cent within 1¾ hr. For this period, the moisture in the steam remained under 1 per cent, which is very good for this type of plant. During the remainder of the test, the ratings carried were those under ordinary operating conditions.

Table IV, as plotted in Fig. 5, illustrates clearly the advantage of carrying low concentrations within the boiler, especially where operating conditions are erratic.

In this test, the steam calorimeter was used for determining the steam quality.

Chemical Treatment to Reduce Total Solids

While it is evident that blowing down is effective in the reduction of total solids, an effort was made to obtain the same result by chemically precipitating the heaviest salt, both in weight and content, the salt being sodium sulphate in this case. A chemical treatment of barium hydrate was, therefore, used, the reaction of which with sodium sulphate being as follows:

$Ba(OH)_2$	$+ Na_2SO_4$	$= BaSO_4$	$+ 2NaOH$
Barium Hydrate	Sodium Sulphate	Barium Sulphate	Caustic Soda

Barium sulphate is precipitated as a sludge and is removed by the filter since the chemical dosage was introduced through the softener.

This test was conducted over a period of 10 days while the barium treatment was gradually increased from a rate of a little over 1 lb. to almost 6 lb. per 10,000 gal. of water treated. Accurate analyses were made each day of the average boiler water of the entire plant. This treatment was entirely effective in producing the results desired, but being costly was abandoned.

It will be noted from the data that the content of sodium sulphate was reduced from 125 to 13.2 grains, by the introduction of barium hydrate and that it furthermore decreased the total soluble solids from a high point of 215 grains to a low point of 122 grains. The blowdown schedule was made constant during the entire chemical test to eliminate any reduction of solids from that cause. The data in

TABLE III. TEST SHOWING THE EFFECTS OF BLOWDOWNS

Observations	Boiler Water		Trap Discharge		Per cent of Boiler Conc.	Hours bet. blows
	Soda	Salt	Soda	Salt		
1	28.3	16.8	18.4	11.2	66.6	3
2	28.2	16.9	7.6	5.6	33.2	1
3	28.4	17.2	8.0	5.4	31.7	1
4	28.9	17.7	10.8	7.2	40.7	1¼
5	27.4	16.6	8.8	5.4	32.5	¾
6	25.0	15.3	5.6	3.4	22.2	¾
7	25.4	15.5	2.2	2.8	10.0	¾
8	25.3	15.3	1.8	1.5	9.1	¾

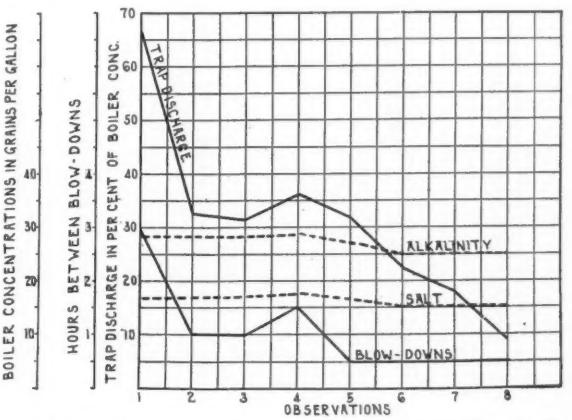


FIG. 4. RELATION OF FREQUENCY OF BLOWDOWNS TO TRAP DISCHARGE

Table V and as plotted in Fig. 6 illustrate the effectiveness of the chemical treatment.

Effect of High Water

It would seem that the effect of high water need hardly be discussed, as it is apparent that such a condition could hardly exist without steam contamination. This point was investigated, however, first because it was believed to be one of the important points in controlling priming conditions at this plant and, second, to note the effect and character of contamination produced.

Figure 2 shows the effects from this cause. In this test, the water level was gradually raised. Its effect upon the steam is apparent. Although, the moisture content at the point of priming is just a fraction above 5 per cent, it is believed that actually this was much higher in view of the fact that a throttling calorimeter was used in the determination.

Figure 7 illustrates practically the same effect even when a steam separator is used within the steam drum instead of a dry pipe. This appliance designed on the centrifugal principle shows that in this case, at least, a mechanical separator is not a panacea for priming trouble. For instance, at the plant investigated, it did not stop the effect of high water in the boilers. In this connection, it should be noted that high water at this plant would be considered a normal operating level at the average plant.

Figure 8 illustrates a repeated test on the same appliance. It is only natural, however, that the result of high water shown caused the effect noted, in that the primary object of such devices is to separate reasonable quantities

of moisture from steam. These tests proved this to be the case.

In considering high water within a boiler as a factor in priming, the reasons for excessive moisture in steam become clear. As is apparent, the surface of the water is

TABLE IV. TEST SHOWING ADVANTAGE OF LOW CONCENTRATION

Time	Rating	Water in Glass	Percentage of Moisture	Load
1:15 P.M.	128	1/2	0.95	Steady
1:30	136	1/2	0.95	"
1:45	136	1/4	0.95	"
2:00	150	1/2	0.95	"
2:15	150	1/4	0.95	"
2:30	153	1/2	0.95	"
2:45	176	1/2	0.90	"
3:00	198	1/2	0.85	"
5:00	128	1/2	0.85	"
5:30	127	3/4	0.75	"
6:00	127	1	0.75	"
6:30	127	3/4	0.75	"
7:00	122	1	0.75	"
7:30	127	1	0.75	"
8:00	132	1	0.75	"
8:30	127	3/4	0.65	"
9:00	127	1	0.65	"
9:30	127	1/2	0.65	"
10:00	127	1	0.65	"
10:30	127	1	0.65	"
11:30	127	1	0.65	"
12:00	127	1	0.65	"
12:30 A.M.	127	1	0.65	"
1:00	136	1	0.75	"
1:30	132	1/2	0.65	"
2:00	127	1/2	0.65	"
2:30	127	1	0.75	"
3:00	127	1	0.75	"
3:30	127	1	0.75	"
4:00	127	1/2	0.75	"
4:30	127	1/2	0.65	"
5:00	127	1	0.75	"
5:30	127	1	0.75	"
6:00	127	1/2	0.75	"

It was found that the type of boiler having tubes arranged vertically is most susceptible to priming and in this classification, by the way, reference is made only to water-tube boilers, particularly the two drum design. These boilers are used as waste heat boilers to a great extent and where the load is steady and the feed water good, no trouble is experienced. When these units are forced, however, under conditions not so ideal, the priming is then experienced.

The horizontal cross drum, inclined-tube sectional header was found to be the type least susceptible to priming, with the longitudinal drum sectional header type next in order, followed by the four drum inclined bent-tube type and the longitudinal horizontal drum straight-tube solid header type. The plant referred to in this investigation is equipped with the last mentioned type of boiler.

TABLE V. RESULTS OF TEST USING BARIUM HYDRATE TO REDUCE CONCENTRATIONS

Days of Test	Laboratory Analysis (Boiler Water) Na_2CO_3	NaOH	Na_2SO_4	NaCL	Total Solids	Barium Treatment Lb. per 10,000 Gal.
1	12.6	14.7	125.	22.9	215.	
2	12.0	24.3	120.	19.6	206.	1.195
3	9.0	19.6	93.5	15.8	173.0	1.55
4	11.0	20.0	90.55	16.0	192.0	2.35
5	12.07	18.92	81.00	15.7	172.0	2.46
6	12.7	14.8	67.7	15.0	171.	3.82
7	--	--	--	--	--	5.88
8	17.95	17.97	46.4	13.2	143.	5.00
9	15.7	33.9	58.2	15.0	145.	4.68
10	16.7	32.6	13.6	14.2	122.	5.18
11	14.24	34.6	14.75	14.8	140.	5.32
12	11.76	18.24	25.60	15.7	125.	--

Na_2CO_3 -- Sodium Carbonate; NaOH -- Sodium Hydrate; Na_2SO_4 -- Sodium Sulphate; NaCL -- Sodium Chloride.

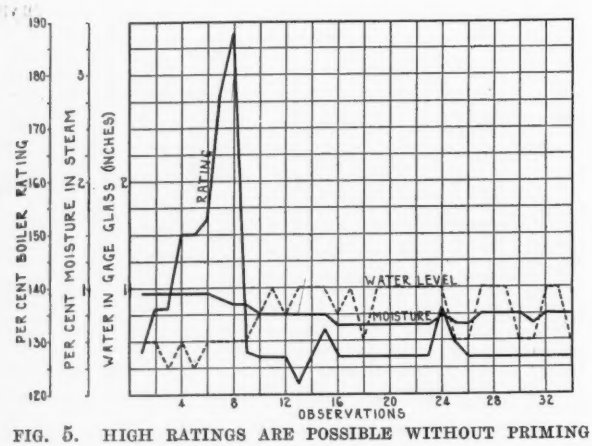


FIG. 5. HIGH RATINGS ARE POSSIBLE WITHOUT PRIMING IF CONCENTRATIONS ARE LOW

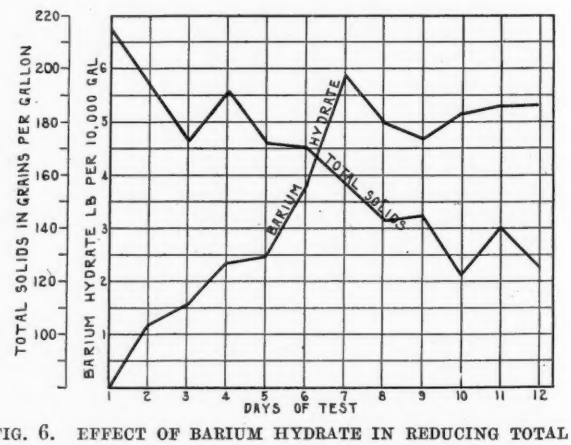


FIG. 6. EFFECT OF BARIUM HYDRATE IN REDUCING TOTAL SOLUBLE SOLIDS IN BOILER WATER

brought nearer to the steam outlet, allowing easier access to the steam discharge.

In most types of boilers, as in this case, the water surface is restricted, resulting in more violent surface agitation for the same amount of steam produced at lower water level.

Types of Boilers

In order to study the influence of various types of boilers on priming, it was necessary to investigate various plants operating under similar conditions with different types of units. Fortunately, the writer is in almost daily contact with power plants in various parts of the country, thus simplifying the matter of classifying the various types of boilers.

It must be remembered in this connection that the influence of the factors described previously carry much weight in these comparisons which should be made under practically the same operating conditions. The longitudinal drum sectional header boiler is better adapted to higher concentrations and erratic operating conditions. This was illustrated to the writer by an inspection of a neighboring plant to the one under investigation, using the same water, softened in the same manner for boiler feed. It is interesting to note that no priming troubles were experienced here even with loads in excess of those carried by the plant under investigation. A plant further up the stream, with the same type of boiler as the one under investigation and with similar operating conditions experiences the same priming troubles.

Steam Separators

As separators within the steam drum are becoming more commonly used, a brief discussion as to their performance and merits would be in line with this investigation. In general, there are two classes, the baffle and centrifugal types. Both types have merits but according to observations also have their limitations as is the case with any piece of mechanical apparatus.

Operation of the centrifugal type separator is shown by Table VI, and as plotted on Figs. 7 and 8. The characteristics are best illustrated by Fig. 8. It will be noted, that as the rating increased the moisture content decreased. This is to be expected, in that this type of separator depends upon velocity for its efficiency. The exact reverse is true of the baffle type, which depends upon low velocities of steam for best results.

TABLE VI. RESULTS OF THREE TESTS OF CENTRIFUGAL TYPE SEPARATOR

Time	Steam Press	Hp.	Per Cent Rating	Water in Glass	Per Cent Moisture	Load
Alkalinity-- 28.0 - - - Salt -- 14.2						
11:15	145	860	143	1/2 Gage	1.0	Steady
11:30	148	860	143	1/2 "	.75	"
11:45	150	870	145	1/2 "	.65	"
12:00 N	150	920	153	1/2 "	.65	"
12:15	150	950	158	1/2 "	.65	"
12:30	150	950	158	1/2 "	.65	"
12:45	150	950	158	1/2 "	.65	"
1:00	150	950	158	1/2 "	.65	"
1:15	150	1020	170	1/2 "	.62	"
1:30	150	1000	167	1/2 "	.65	"
2:00	150	1000	167	1-1/2 "	4.6	"
3:00	150	1000	167	1 "	.75	"
Alkalinity gr/gal. 17.4, Salt gr/gal. 11.2, Total Solids 105.0 gr.						
3:15	148	740	123.3	1/2 Gage	.75	Steady
3:30	150	1000	166.6	1-1/2 "	1.2	Rising
3:45	149	1030	171.6	1-1/2 "	2.25	Rising
4:00	149	1130	188.3	1/2 "	.6	Rising
4:15	151	1180	196.6	1/2 "	.5	Steady
9:30			123	1/2 Gage	1.25	
9:45			97	1/2 "	2.25	
10:00			123	1/2 "	1.09	
10:15			117	1/2 "	0.80	
10:30			137	1/2 "	0.75	
10:45			132	1/2 "	0.80	
11:00			192	1/2 "	0.60	
11:15			167	1/2 "	0.80	
11:30			198	1/2 "	0.50	
12:00			116.6	1-1/2 "	4.50	

Apparently, the centrifugal separator works efficiently, but it must be remembered that this test was conducted on a boiler having a low concentration of boiler water, 105 grains to be exact. Later tests upon the centrifugal separator with concentrations under normal operating conditions indicated a less encouraging result.

Conclusions

From the tests described herein, the first important consideration in the prevention of priming, is a careful control of the boiler concentrations. From Fig. 5 it is quite evident that if these concentrations are carried low enough, no trouble should develop from this source. It is interesting to note, however, that there is a different priming point for each rating. Thus, in the foregoing tests, it was pointed out that with concentrations of approximately 60 grains, a rating of over 200 per cent could be carried quite easily, while at 100 per cent rating, a concentration of total solids of over 280 grains could be carried without experiencing wet steam.

It has been pointed out that two methods can be employed to make control of concentrations effective; namely, that of blowing down and the use of barium salts—in this case, barium hydrate.

Of the two, blowing down is preferable, because of its much lower cost and ease of regulation. There is a well-established opinion among boiler plant operators, nevertheless erroneous, that blowing down a boiler beyond a fixed schedule is expensive, even under priming conditions.

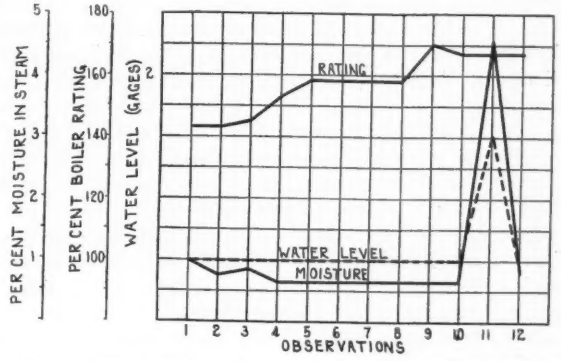


FIG. 7. EFFECT OF HIGH WATER ON OPERATION OF CENTRIFUGAL TYPE SEPARATOR

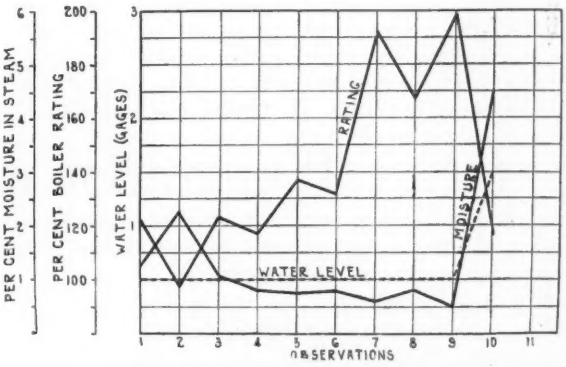


FIG. 8. CHARACTERISTICS OF CENTRIFUGAL SEPARATOR

It must be remembered, however, that a priming boiler, in effect, is blowing down itself through the steam outlet. Considering the probable effect of neglect of blowdowns to reduce concentrations, in the way of certain types of expensive repairs and shutdowns, the fallacy of blowing down without knowledge of concentrations becomes apparent.

Chemical treatment with barium hydrate should be used with caution and is to be recommended only with waters high in sulphate content. In the particular case under investigation, the treatment was discontinued in that its cost was $14.00 a day for achieving the same effect as blowing down, which cost $9.00.

In this connection, there is another point to be considered. Where the boiler water is alkaline the possibility of caustic embrittlement must be considered. It has been emphasized by authorities on this subject, that no case of caustic embrittlement has ever been cited where the relation of sulphates to alkaline sodas is one to one. In all known cases of caustic embrittlement, the boiler waters were always low in sulphates and chlorides. This condition exists in two plants under the writer's observation, in which caustic embrittlement has been a problem, one in Colorado and one in Texas.

While this rule may be only a coincidence, in the light of our present knowledge of this subject precautions that have an inhibiting effect on this condition should be observed.

In referring to the table giving the details of the barium hydrate treatment, it will be noted that the sulphates were reduced below the content of the total of the sodium carbonate plus the caustic soda. In such cases, the barium treatment should be avoided, if for no other reason than to avoid a possibility of caustic embrittlement.

Function of Mechanical Separators

Having found that there is a different priming point for every rating, it becomes apparent that the efficient regulation of concentrations becomes a difficult problem. Where mechanical separators are in use, this regulation need not be so exact, in that they take care of reasonable priming, as it occurs, insuring dry steam at all times. It must be remembered, however, that separators do not prevent or remedy priming conditions—they simply correct the effects.

When a concentrated water builds up to the priming point within a boiler, the water must be relieved through the blowoff valve or it will relieve itself through the steam outlet. The separator then becomes an automatic blowoff in effect. Where the concentrations become excessive through neglect of blowdowns, so much water is relieved that the separator becomes flooded, consequently failing to function for the purpose it was intended, that is, the elimination of all moisture. The control of the concentrations, therefore, becomes an important item even when these devices are used.

Where comparatively steady load conditions prevail, regulation of concentrations below the priming point, by means of the blowdown, becomes a simple operation. Such was the situation in the plant investigated. For this purpose, a continuous blowdown would be most effective, passing the hot blowdown water through a simple heat exchanger, in which the heat of the blowdown water is transmitted to the cold incoming raw water. Obviously, the loss due to blowing down is reduced to a minimum and relief from priming assured.

Type of Unit

As the reader has observed, from the foregoing, priming troubles are caused primarily by the selection of boilers not adapted to specific water and operating conditions. When steaming units are to be replaced, serious consideration should be given to these factors, for while price and construction details have their place in the investment, it naturally follows that the investment is enhanced if a choice is made between a boiler susceptible to priming and one that delivers dry steam.

Mechanical stokers are generally selected to conform to the grade of coal to be burned and the operation desired. Since the primary function of a boiler is to evaporate water for clean steam, should not the quality of the water at least be given equal consideration with the other factors in the selection of boilers?

Preparation of Pulverized Coal[1]

Drying Coal Preparatory to Pulverization Is in Some Cases a Seasonal Problem. By H. G. Barnhurst*

PULVERIZED-COAL firing has been so extensively adopted for boilers during the past few years that the methods of preparation of the fuel have become a matter of considerable interest to the engineering profession in general. Three operations, crushing, drying and pulverizing, are generally required and in addition, proper means of transportation of the material are necessary. Crushing is eliminated when the coal as received is already small enough to be a satisfactory mill feed. Drying, likewise, may at times be eliminated when the moisture content of the coal as received is low but as this is largely a seasonal characteristic, elimination of the drying equipment is not always advisable.

Crushing operation is necessary, not only to reduce the coal to a size suitable for the pulverizers, but also to expose larger surfaces to the hot gases used for drying. Any standard type of crusher can be used, but crushers having the ability to reduce the coal to proper size in one stage and without excessive consumption of power are preferable. To make a satisfactory mill feed, the product of the crusher should pass a 1-in. or 1¼-in. ring to suit the present standard sizes of mills. Coal may be stored before or after crushing. This does not affect the pulverizing, and is generally determined by the plant layout.

Necessity of drying the coal before pulverizing has been often called into question, particularly by operators whose coal supply is normally of low moisture content. The facts are inescapable, however, that drying the coal considerably increases the capacity and reduces the power consumption of the pulverizers, and makes its handling after pulverizing a positive instead of a doubtful operation. Damp pulverized material is hard to handle, hanging up and blocking at every point possible. Its transportation is unreliable and a continuous annoyance. Even when coal is dry as normally received, there will be occasions when the weather will make drying essential.

One Type of Drier Is Direct Fired

Two types of driers are available: the rotary, which has been standard for many years, and the vertical stationary type, of comparatively recent development. The former consists of a rotating shell, slightly inclined, and ribbed internally, through which the material passes by gravity in conjunction with the rotation of the drier. The hot gases are usually passed around the outside of the shell before entering and flowing through it in direct contact with the material, which is picked up by the ribs and dropped across the path of the gases. This is known as the indirect-fired type of rotary drier.

The vertical drier is a sectional box through which the coal flows by gravity on its way from the storage bin to the pulverizer. Hot gases under fan pressure or suction pass through the interstices in the body of the material and carry off the moisture. These gases are preferably taken from the boiler stack, in which case the term "waste-heat drier" is usually used. Steam-heated surfaces may also be incorporated in this drier, to assist the evaporative action of

[1]Abstracted from a paper presented at a joint meeting of the Cleveland Engineering Society and the Cleveland section of the A. S. H. V. E. and A. S. M. E.

*Advisory Engineer, Fuller-Lehigh Co.

the gases. The fact that this drier is stationary and occupies much less space than an equivalent rotary drier, not to mention its lower cost, makes it preferable under certain conditions. Cyclones are essential for removing the dust in the discharged gases from a rotary drier, and are desirable with a vertical drier, particularly when the coal contains a considerable proportion of fines.

Sometimes the magnetic separator is installed ahead of the crushers instead of after the drier. It is essential to keep iron out of the pulverizers, as it increases the cost of repairs and causes delays. These magnetic separators may be of the lifting type, although in some installations the pulley type is used. The elevator used for delivering the dried coal to the bin above the pulverizers may be of the chain-and-bucket type, and steel encased to eliminate dusting. In some cases the elevator discharges directly to the bins above the pulverizers and in other cases it discharges into a screw conveyor running in a dust-tight, sand-sealed trough, the elevator and conveyor usually being driven by the same motor. The bins above the pulverizers should be large enough to supply the mills for two or three hours, thus permitting a steady feed and allowing some leeway in case anything happens to the drier or elevator drives.

Transporting the Pulverized Coal

When the coal has been pulverized, it must be transported to the point of use. A number of methods are available, the oldest being the spiral screw conveyor, operating in dust-tight steel troughs. Another conveying system consists of a pressure-tight tank, a source of compressed air, and a pipe line leading from the bottom of the tank to the destination. In operation the tank is nearly filled with pulverized coal, sealed, and compressed air is then admitted above the coal, which forces the latter through the pipe line, discharging from the line into the furnace bins. A third system, which is rapidly coming to the fore, consists of a pump having as an impeller a high-speed steel worm, which takes the pulverized coal from a hopper and forces it into a pipe line. A small amount of compressed air is admitted into the material just beyond the discharge end of the worm, and the mixture of air and coal is forced through the pipe line to the destination.

Complete electrical signaling systems are used to indicate to the operator when the bin to which he is pumping has been filled, and to permit him to operate diverting valves to change the flow to other bins which are in need of coal. The operation is usually made automatic, in order to avoid any chance of overflow.

This latter system of conveying has been used to elevate pulverized coal over a hundred feet, and to convey it distances of over a mile, the line pressure and the power required, which is comparatively low, depending upon elevation and distance. Little compressed air is required, hence no cyclone is needed at the point of discharge from the pump line. The material as discharged is completely fluid, and levels off perfectly in the bin, retaining this condition for some time.

Cost of preparation of pulverized fuel may be divided into five main items: power, labor, repairs, fuel for drying, and interest and depreciation. Of these, drier fuel might logically be eliminated, inasmuch as its effect is largely returned in increased heating effect of the coal burned under the boilers. Approximately 1 per cent of the total fuel used is required for drying, and when waste heat or steam is available the item disappears. The remaining items decrease as the capacity of the plant increases and it is this fact which accounts for the commanding position now assumed by pulverized coal in the field of large power plants.

No set figures can be given for the ratio between these items, as they will vary irregularly with locality and with size of plant, but a maximum of 20 kw-hr. per net ton of bituminous coal may be stipulated, covering the entire process from crusher to furnace, and the charges for power, labor, and repairs may be taken roughly as in the ratio 5:3:2. These three items in a plant having a capacity of 400 T. per day, assuming power available at 1 cent per kw-hr. and labor at 50 cents per hour, would amount to 18 cents, 10 cents, and 8 cents, respectively, or a total of 36 cents per ton without financial charges.

Economy and Efficiency Compared

By N. G. Near

SOME hard-shell lovers of argument claim that such an expression as "economical efficiency" is ridiculous and superfluous—that efficiency naturally includes economy. The writer, however, claims that there are four ways of looking at it and that all four may be correct.

First, there is economy alone, which involves a great many points in its definition. In general, though, economy means "making a dollar do as much as possible" regardless of conservation of natural resources, regardless of refinement of machinery and regardless of life of machinery. A machine does not necessarily have to be efficient in order to be economical. Thus the thermal efficiency of a steam engine may be 10 per cent and the thermal efficiency of a gasoline engine may be 20 per cent. Yet it is possible for the steam engine to be more economical because of the cheapness of coal as compared with gasoline.

Second, there is efficiency alone, which has a great variety of meanings. Thus an engineer who is constantly on the alert may be called an "efficient" engineer because of his vigilance. A machine is called efficient when it does almost as much as it can possibly do under ideal conditions. An efficient electric generator, for instance, is one that transforms most of the mechanical energy into electrical energy. Efficiency is generally measured by dividing the output of energy by the input of energy. Efficiency during the war applied to practically everything—governments, soldiers, ships, men, aeroplanes, machines, etc. All of these things may be efficient, yet they may not be economical.

Third, we have economical efficiency, which may mean that a machine, say, is both efficient and economical. Or, it is economical in spite of its efficiency. If a thing is economically efficient it may be considered as being at its best. For example, it may be possible to utilize 25 per cent of the heat in coal by the use of machinery whose first cost would be $1,000,000 per horsepower. Such a steam engine would be an "efficient" machine, but it would not be economically efficient. In the whole cycle of first costs and operations there is just one combination that represents the height of economical efficiency. The only way in which that point can be determined is by endless experimentation and computation.

Lastly, we have efficient economy, which means that a machine needn't necessarily be efficient but it must be economical and this economy must be cared for in an efficient manner.

Use of Liquid and Gaseous Fuels*

MECHANICAL BURNERS ARE POPULAR. VENTILATED FURNACE CONSTRUCTION REDUCES BRICKWORK FAILURES

KNOWING WITH certainty the condition of fuel oil at or near the bottom of storage tanks is important because of the possibility of the presence or water in either the free state or in objectionable quantities as an emulsion. Serious trouble is often experienced through the presence of a large amount of free water in the bottom of a storage tank. In fact, there are cases on record where a general shut-down of an entire plant resulted because of water being pumped to the burners in a quantity sufficient to extinguish the fires.

By sampling at regular intervals, particularly after cargo receipts, the exact condition of the oil at any depth in the tank can be known at all times. In case water is found in excessive quantities a sufficient amount of the bottom contents of the tank should be pumped to a special separating tank, where, by applying heat, the water can be separated from the oil, discarded and the oil returned to the storage tank. Another way to avoid trouble from water in underground storage tanks is to use a floating pump suction.

CONSTRUCTION OF FURNACE FLOORS

Engineers of the H. M. Byllesby Co. have designed a ventilated furnace floor which is constructed as follows: Vitrified clay tile, each containing six ducts 3½ in. square (two high and three wide) are laid on a concrete base over the whole area of the furnace floor so that air enters at the front from the basement and passes through the ducts to a header across the rear of the furnace. From the header the air is led through each sidewall and is discharged through steel chimneys 9 in. by 21 in. by 9 ft. 6 in. high at the sides of the boilers. Over the tile is placed 5 in. of crushed firebrick and then two courses of firebrick. Air circulation is by natural draft. The velocity of the warm air in the chimneys is not high and the temperature in the ducts 6 ft. from the front does not go higher than 235 deg.

One peculiarity in the operation of some burners and the furnaces is a puffing or pulsating of the fires which takes place when they are forced too much. Lack of sufficient air seems to be the cause of this trouble in some instances although more damper opening and more draft does not always stop it without reducing the fires.

In a plant recently placed in operation on the Pacific Coast no attempt was made to ventilate the walls of the furnace but a scheme for ventilating the furnace floor was adopted. The air entered through a grating at the side of the setting and after passing through a duct back of the bridge-wall, traveled under the furnace floor to the front of the boiler. Enough air circulation was obtained in this manner so that the brickwork on the furnace floor was maintained in a satisfactory condition.

After operating for 1450 hr. with an average rating of 178 per cent, with occasional peak loads of 200 per cent, it was found that due to spalling and melting of the brickwork, the furnaces would have to be relined for a distance of about 10 ft. from the furnace floor. With this arrangement barely 200 per cent could be obtained and that only with heavy pulsations, which caused damage to brickwork and baffles. In order to overcome the pulsations and give increased rating, four more burners of the same type were added to each boiler and placed above the existing ones.

CHANGES MADE TO SETTING

In replacing the walls a new scheme of furnace ventilation was tried out. The boiler front was made double so that air could be drawn through the walls. The hollow tile in the furnace floor was replaced at right angles to the

*Abridged from the Dec., 1924 report of the N. E. L. A. Prime Movers' Committee Report.

FIG. 1. PORTION OF A REAR WALL AFTER 820-HR. OPERATION

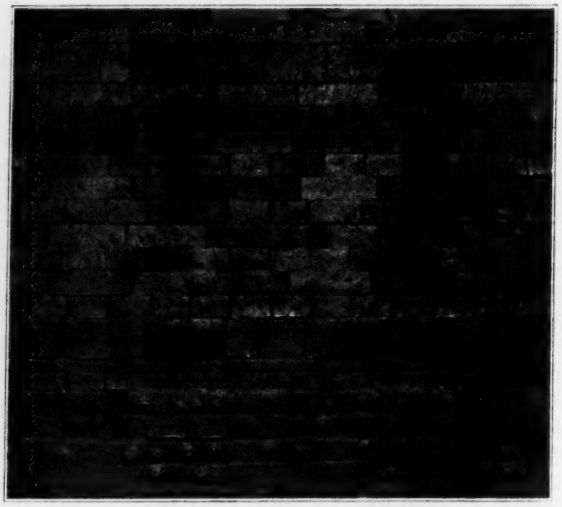


FIG. 2. NEAR VIEW OF PART OF FRONT WALL AFTER 820-HR. OPERATION

FIG. 3. THIS FURNACE WALL HAD BEEN IN OPERATION FOR 3984 HR.

original installation and the whole battery ventilated as a unit. Air passed in the side of the setting through each bridge-wall and then into the furnace. Air was only allowed to enter at each side of the battery, a portion of it being drawn to the opposite side and then up and around to the burners at the front, the rest being drawn to the battery wall and up and around to the burners.

The two boilers with their reconstructed furnaces were placed in operation and were operated for about 22 hr. a day at about 190 per cent of rating, with occasional peaks of 250 per cent. After the furnaces were rebuilt with the additional burners, the difficulties from pulsations largely disappeared, although in operation the burners are somewhat sensitive to changes in draft. Measurements with an optical pyrometer showed the furnace temperature to be from 2900 to 3050 deg. F.

Side wall cooling, by allowing a small amount of air to be drawn into the furnace through ⅛-in. openings in the vertical joints between the brick, is now in use. This method permits about 10 per cent of the air to be drawn in through these openings by the slight negative pressure in the furnace. This air coming in as it does where there is flame impingement and where combustion is intense does not reduce the efficiency and the life of the brickwork is about three times that with solid wall construction.

Walls of this kind should be made of first quality firebrick laid up as headers with the spaces in the vertical joints. Bricks which have a slight tendency to spall are preferable to those which melt and glaze over, as the latter seal up the air spaces and the cooling effect is lost. Perforated fire clay blocks have been used in some cases.

Results of Tests

Tests Nos. 1 to 10 shown by the curves given herewith were run on an oil fired boiler as found after about 3 mo. of service. The heating surfaces were not clean, the baffles needed slight repairs, and the top of the front baffle was as left when Turner baffles were installed, which left an opening of about 2½ in. between the superheater elements

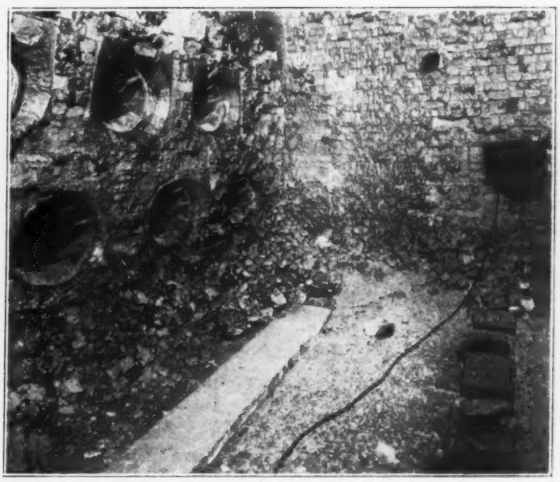


FIG. 4. FRONT AND SIDE WALL AFTER 95 DAYS OPERATION DURING WHICH TIME FURNACE TEMPERATURE REACHED 3050 DEG. F.

and the top of the baffle. After the first series of tests boiler changes were made as follows: The first baffle was built up to the superheater, the rear baffle pointed up, heating surfaces washed clean and air leaks at front and rear headers stopped.

Tests Nos. 11 to 16 inclusive were then made. These showed higher efficiencies, higher superheat, higher CO_2 and lower stack temperatures and the draft loss and steam pressure drop remained the same. The steam pressure drop showed that with the highest ratings, line pressure was about 30 lb. below boiler pressure. Combustion rates varied from about 3¼ to 6 lb. of oil per cu. ft. of furnace volume, the average having been about 4.4 lb. per cu. ft. for the year. Lower ratings than shown can be secured with this system by using a smaller sprayer plate.

Combination of gas and oil firing continues to be a subject of considerable interest. The latest development is the successful burning of high pressure gas in combination with mechanical oil burners. The Southern California Edison Co. has satisfactory installation which consists of a multiplicity of 3-in. Bunsen burners grouped horizontally in the floor of the furnace in front of the original air space for the rear shot Hammel oil burners, which are left in place as originally installed.

For an 850 hp. Stirling boiler there are 320 of these burners occupying a space of approximately 6 by 15 ft. in the front portion of the furnace floor. Burner tubes are cut from discarded 3¼-in. boiler tubes, around the top of which is moulded a plastic refractory which is allowed to extend from 4 to 6 in. above the metal portion of the tube. Gas is admitted at the base through a $\frac{3}{16}$-in. opening, drilled in a ½-in. pipe, and at a pressure varying from ½ to 1 lb. A swinging damper pivoted at its rear serves to deflect air either to the gas burners or oil burners as desired. Capacities up to 200 per cent of rating have been obtained with this equipment using gas fuel. Good combustion control is easily secured. The change from gas to oil is readily made, or both gas and oil may be burned simultaneously.

If the oil burners are left in place while gas is being burned a slight amount of steam must be allowed to flow through the burners to keep them cool. When oil is burned for a considerable length of time in these furnaces slag-

ging will sometimes clog up the gas burners nearest the wall giving some trouble when the gas is again used. This, however, is easily removed when the boiler comes out of service. No other defects have been observed in 3 yr. experience with this type of burner. The cost and maintenance of this installation is low and it is found satisfactory for Stirling boilers with low settings.

One type of gas burner, which can be used in combination with forced draft mechanical oil burners, has been developed and patented by R. H. Farney of the Dallas Power & Light Co. This equipment was developed with the idea of producing a burner which could be made up at comparatively low cost and applied to new

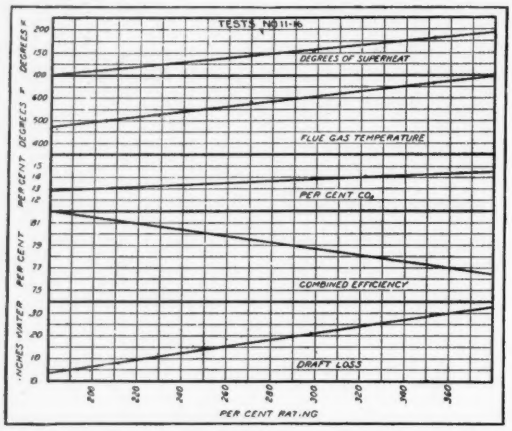


FIG. 5. RESULTS OF TESTS BEFORE ALTERATIONS WERE MADE

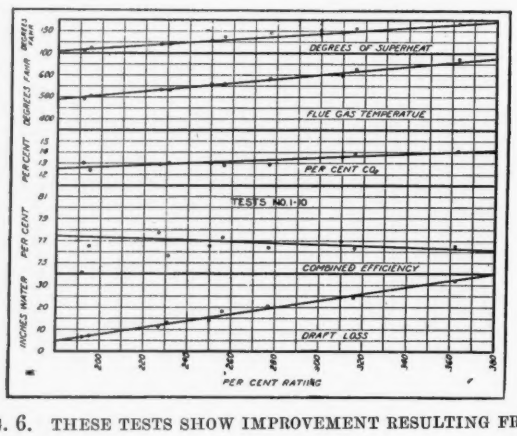


FIG. 6. THESE TESTS SHOW IMPROVEMENT RESULTING FROM IMPROVED CONDITIONS

or old oil burning installations where it was desired to burn both oil and gas.

Tests were made with these high pressure gas burners firing a 1700-hp. B. & W. boiler set with 5500 cu. ft. of combustion space. The boiler was equipped with seven San Diego mechanical oil burners and there was no change made in the burner, except that part of the burner known as the atomizer was removed and a gas burner inserted in its place. The air for combustion was obtained in exactly the same manner as when burning fuel oil.

During the test, as in normal operation, the 1¼-in. gate valves to the individual burners were wide open and the gas pressure was controlled by a 6-in. globe valve. A 6-in. gate valve was installed ahead of the globe valve to insure a tight cut off when needed. The boiler had a ventilated setting and the uptake damper was automatically controlled to give a differential draft between the fire box and the ventilating duct of from 0.05 to 0.10 in. of water.

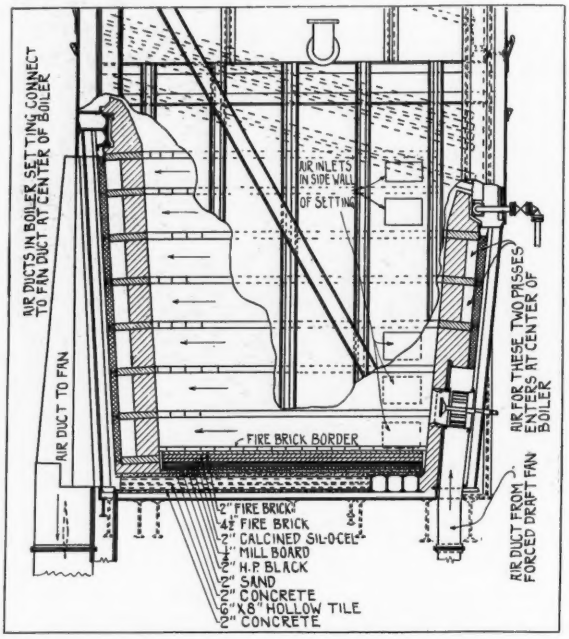

AIR DUCTS IN BOILER SETTING CONNECT TO FAN DUCT AT CENTER OF BOILER
AIR DUCT TO FAN
AIR INLETS IN SIDE WALL OF SETTING
FIRE BRICK BORDER
AIR FOR THESE TWO PASSES ENTERS AT CENTER OF BOILER
AIR DUCT FROM FORCED DRAFT FAN
2" FIRE BRICK
4½" FIRE BRICK
2" CALCINED SIL-O-CEL
1" MILL BOARD
½" H.P. BLACK
2" SAND
2" CONCRETE
6" X 8" HOLLOW TILE
2" CONCRETE

FIG. 7. VENTILATED FURNACE CONSTRUCTION USED BY A PUBLIC UTILITY COMPANY

Tests were run from 137 per cent to 268 per cent of normal rating. At 225 per cent of rating it was found that the uptake damper was wide open and in order to get higher ratings it was necessary to increase the windbox pressure more than would be otherwise required. This reduced the fire box draft and tended to push the gases through the boiler. In order to hold the differential draft between the fire box and the ventilating duct it was necessary to bypass the ventilating duct partially for ratings above 225 per cent, which reduced the draft in the ventilating duct and allowed the fire box draft to be still further lowered, thus permitting more air to be passed and the rating increased.

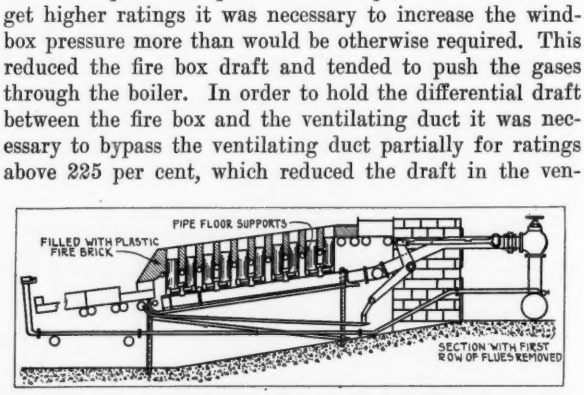


FIG. 8. GAS BURNERS PLACED IN THE FURNACE FLOOR

The burners gave good combustion throughout the entire range without any adjustment of the burners or air register. To change the rating, all that was necessary was to change the gas pressure with the main globe valve and adjust the wind box pressure accordingly. The combustion was slightly better at high ratings than at low ratings, due, doubtless to better mixing. At all ratings the fire was transparent and no flame was visible. One could easily see entirely across the furnace without colored glasses. There was no glare, the brick work being a light straw color.

Deterioration of Turbine Blading in Service

Discussion of Causes and Prevention by British Engineers. Reported by C. H. S. Tupholme

SUMMED up under six heads, the main causes of deterioration in service of turbine blading are as follows: 1. Chemical action of hot steam on the metal. 2. Chemical corrosion due to impurities in the steam. 3. Rusting. 4. Erosion due to water in the steam. 5. Erosion due to boiler mud carried over in the steam. 6. Erosion of low-pressure stages by metallic particles eroded out of preceding stages. These causes recently formed the subject of an interesting discussion at the Rugby Engineering Society, one of the British engineering centers.

According to J. C. Read, trouble No. 1, chemical reactions, is confined to the high temperature region, and only occurs with certain materials, such as aluminium bronze. This alloy has a composition of 7 to 10 per cent aluminium, with sometimes 2 to 3 per cent iron, the remainder being copper. It is found that under the influence of hot steam a decomposition of the surface of the bronze blades sets in, as a result of which the aluminium disappears from the outer layer, leaving a layer of copper in an intensely brittle state, which easily breaks off in flakes about 1 mm. thick. The core of the metal is not affected, but as the decomposed surface flakes off fresh metal is exposed to the action, so that the metal wastes away, the thin parts being naturally affected first.

When the enormous volume of steam which passes through the turbine in the course of a few years' service is considered, it is easy to see that a small fraction of one per cent of impurities in the steam may be sufficient to cause chemical corrosion. Admixture of magnesium chloride or calcium chloride in the make-up water is mainly responsible for this. In the presence of steam at high temperatures these salts are decomposed and acid vapors are given off. The feed water may also become contaminated by leaky condensers, with consequent penetration of sea water, mine water or sewage. Brass and nickel brass are proof against the acid vapors thus produced, but aluminium bronze is rapidly corroded, particularly in the temperature range between 130 and 70 deg. C.

Presence of sea water in the steam may be detected by adding four or five drops of decinormal $AgNO_3$ solution to a test tube full of the condensate. On shaking up, the extent of the contamination is indicated by a more or less heavy precipitate.

Kerosene Reduces Corrosion

The addition of kerosene to the steam supply has proved effective in some cases in reducing corrosion, since the kerosene forms a protective film on the face of the blades. A small hand pump is connected to the steam main, and a few pumpfuls are injected occasionally. Corrosion has also been successfully prevented in Parsons marine turbines by whitewashing the blades.

Rusting is a form of corrosion to which only the ferrous alloys are subject. It attacks all steel parts in the turbine, but is particularly injurious to the blading on account of the thinness of the parts there exposed. Both oxygen and liquid moisture must always be present so that rust may form, and the presence of carbon dioxide accelerates it.

Rusting during operation may occur due to air mixed with the steam. Occasionally it may also occur when running at loads so light that the high-pressure gland is under vacuum, when, if the sealing steam is insufficient, air will be drawn in, and in passing with the steam to the condenser will cause rusting. The remedy for this is obvious. Oxygen and carbon dioxide may be kept from mixing with the feed water by reducing air leaks to the minimum and by not allowing the feed water to come into contact with the atmosphere at any part of its cycle.

Most serious rusting occurs while the turbine is standing idle. The machine is then full of air and any small leakage of steam into the casing will cause rust to form, though it is worth noting that if the leakage is great enough to keep the entire turbine too hot for moisture to be precipitated, no rusting will take place. For this same reason, when the leakage is small, small parts such as blades and shroudings show far heavier formation of rust than do such parts as the disks, which are large enough to remain hot.

Similarly, a plant which has been free from rusting for several years may suddenly rust up heavily without any apparent change in the operating conditions, due simply to a small change in the amount of the steam leakage.

Rust which has formed while the machine has been standing idle may frequently be distinguished by a heavier deposit on one-half of the wheel than on the other. The remedies for this form of rusting are: (a) there should be two valves in series between the turbine and the steam supply, and the pipe between them should be connected to the atmosphere when the turbine is not in use, and (b) the air pump should be kept running for some time after shutting down, in order to dry the inside of the turbine.

Erosion due to moisture in the steam is totally different, both in appearance and in the method of its production, from the erosion produced by solid particles carried in the steam. Whereas erosion caused by boiler dust presents a sand-blasted appearance extending over almost the whole of the concave face, water erosion, on the other hand, is seen by fine scoring, which is confined to the entrance edge and is found only on the back, or convex side, of the blade.

The reason for this difference lies in the fact that much of the water does not travel suspended in the steam, but collects, probably due to its greater weight, as a film on the convex face of the fixed blade or nozzle-plate. The retarding effects of surface tension and viscosity cause this film to be blown forward at a comparatively slow rate by the steam passing over it. It thus drips from the edges of the fixed blades, whose backs, striking it with considerable force, become gradually worn. Once the moving blade has shattered the water particle and given it a velocity practically equal to its own, erosion ceases, and is not found again on that row of blades.

When the water leaves the moving blade the condition is somewhat different, since in this case the drops are for the most part hurled off in a radial direction. As a result, water erosion of the fixed blades is comparatively rare; it also follows that the turbine automatically separates much of the moisture from its steam at each stage. In consequence this form of erosion can be largely avoided by efficient draining at each stage.

Though not the commonest, the most serious form of

erosion is that due to boiler dust in the steam. When the boiler primes, a certain amount of mud is carried over with the moisture and is converted into dust in the superheater. Steam and mud traps cannot remove the whole of this dust unless they are interposed between the boiler and the superheater, so as to precipitate it as mud with the water with which it is associated.

Often, of two turbines supplied from the same steam pipe, one may be badly eroded and the other almost unharmed. In such cases it is always the machine at the end of the steam main which gets the wear.

Erosion by boiler dust appears in the first high pressure stage, and in bad cases also in the high pressure intermediates. When the steam has been expanded down to saturation, the dust is again converted into mud, and deposited on the blading. Marked erosion is often noticeable at the point where the steam passes from superheat to saturation, due to this cause. The gradual wear and choking up of this stage results in an increased end thrust, and is detected by a slow increase in the running temperature of the thrust bearing. The use of kerosene previously mentioned is of value in loosening this deposit and a case is recorded in which the deposit was dissolved out without dismantling the turbine, by means of a solution of sodium carbonate.

Under certain conditions this trouble may be accentuated. The presence of soda, or worse still, of salt, gives rise to violent foaming in the boiler, and may cause it to boil over. In this case large quantities of mud and frothy water get into the steam main. The mud passes into the turbine and suddenly chokes up the low pressure stages, throwing a heavy bending stress on the blades, and causing considerable heating in the thrust bearing.

Particles of metal dislodged from the blades in the early stages of the machine are carried forward by the steam, and assist in the erosion of the later stages. At first sight it might appear that the amount of metal carried through in this way would be negligible, but that this is not the case is shown by an illustration published recently. This showed a group of stainless steel blades in a turbine whose remaining blades were of 5 per cent nickel steel. Dark patches are visible on the stainless steel blades, and these consist of rust which has been formed in preceding stages, carried through and deposited. A slight rub with a cloth was sufficient to dislodge this rust, leaving the original shining surface of the stainless steel.

In another case of a turbine having bronze high-pressure blades and steel low-pressure blades, the deposit which formed in the corner where the blade and shrouding meet was removed from one of the steel blades, and on analysis was found to contain copper, which could only have come from the bronze blades.

Accurate Balancing of Machine Rotors

Method of Balancing Rotative Machine Parts which Gives Greater Accuracy Than the Old Cut and Try Method. By C. R. Soderberg

ACCURATE methods of rotative balancing are usually associated with more or less elaborate balancing machines but balancing machines are not as yet to be found in every shop. At the present time, cases requiring extraordinary accuracy are frequently solved by the old methods of hand balancing, that is, the rotor is run at a high speed in its own bearings and the corrections applied by cut and trial until quiet running takes place. The corresponding process in a balancing machine is characterized by superior accuracy and a more definite procedure, requiring less skill and time. The improved accuracy, as compared with hand balancing, is due to the application of the resonance principle, whereby the effects of impulses from a minute unbalance are made to accumulate into appreciable motions.

In a number of cases it is possible to apply the resonance principle to hand balancing as well, thereby obtaining fully as accurate a balancing result as that possible in a balancing machine. This method of improved hand balance was first applied to the balancing of a motor generator set. The arrangement was as shown in Fig. 1. The armature has a balancing disk on each end, providing a convenient method of applying the corrections. The fundamental principle of the arrangement is to provide an axis of oscillation in the plane of the balancing disk at one end, while the balancing is performed in the plane on the other end. For this purpose the bars E and F are attached to the frame half. Each bar has two bolts, A, B. C, and D, which can be lowered to engage in the cups G, or raised to place the weight on the coil springs H. The armature is rotated by its own power and the oscillations of the frame around the pivot axis are indicated by the dial gage I. When the speed of rotation of the armature coincides with the natural frequency of vibration of the suspended frame, the impulses from the unbalance become cumulative and the amplitude of motion becomes large even for an extremely small unbalance.

Reasons for placing the pivot axis on the plane of the balancing disks are evident from the diagrammatic sketch Fig. 2, which is a horizontal view of the rotor and the corresponding locations of the pivot bolts. The unbalance in the armature can always be corrected by two masses; one in each of the two balancing disks. This is true whether the unbalance is entirely static, dynamic, or a combination of both. When the bolts A and B are lowered into the cups and those at C and D are raised to transfer the weight to the springs, the frame will oscillate around the axis A-B under the influence of the unbalanced centrifugal forces. The component in the plane A-B exerts no moment. The component in the plane C-D can then be done away with by a weight in the balancing ring on that end.

When this is done, the pivot axis is moved to the plane C-D by lowering the bolts C and D and raising A and B. Then the component in the old pivot plane becomes effective but that in the new pivot plane, whether corrected or not, produces no moment. When the oscillations of the frame around the axis C-D are done away with by a weight in the balancing ring in the plane A-B, the rotor is in perfect balance.

Location of the correction weights are obtained by marking the shaft of the rotor. As might be expected, the results of this marking are extremely erratic, if made when the rotor is rotated at the critical speed. At that speed the mark should, theoretically, lag behind the unbalance by 90 deg. but an extreme speed variation produces great changes of this angle of lag. More consistent results are

obtained by doing the marking at a speed slightly above the critical speed. Then the mark lags behind the unbalance somewhat less than 180 deg. and the correction is applied slightly behind the mark.

Accurate results have been obtained by this method of balancing. The rotor, illustrated in Fig. 1, weighs about 750 lb.; the balancing weights are applied at a 5-in. radius and the distance between the two balancing disks is about 40 in. An unbalance of 0.1 oz. produces an amplitude of motion of about 0.004 in. with the indicator mounted as shown in the figure. This unbalance represents 1/90000 of the weight of the rotor. It was found that about twice this amount of unbalance could be tolerated without appreciable vibration at normal operation of the set.

Pending the construction of suitable balancing equipment a similar method of balancing has subsequently been applied to turbo generators of medium size. The arrangement is shown schematically in Fig. 3. The rotor is rotated in ordinary bearings 1, which are mounted on the curved beams. These beams are provided with pivot bolts, 3, and springs, 4, in a similar manner as are the bars

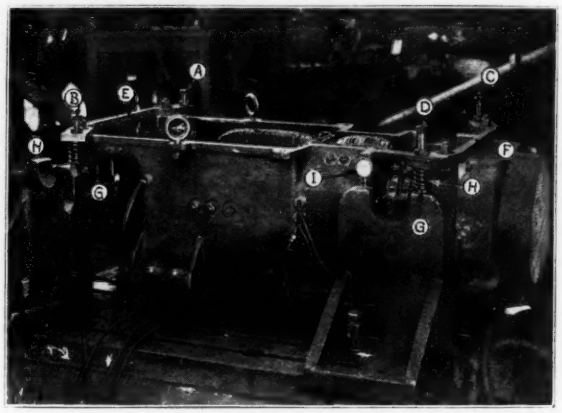


FIG. 1. VIEW OF MOTOR ROTOR MOUNTED IN ITS OWN BEARINGS PREPARATORY TO BALANCING

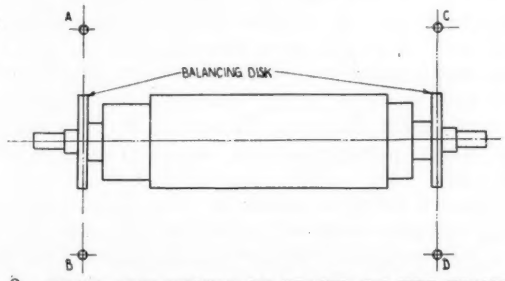


FIG. 2. PIVOT AXIS SHOULD BE PLACED ON THE PLANE OF THE BALANCING DISKS

used in Fig. 1 but only one in each end is designed to be released. By this arrangement sufficient rigidity in the lateral direction is obtained. A device, 5, maintains the rotor in the axial direction and carries possible end thrust. The rotor is rotated by a driving motor, 6, through a belt. The oscillating motion is indicated by a common dial gage indicator, 7.

Since it is not possible to place the axis of oscillation in the balancing planes, the balancing operation is somewhat more complicated. Assume that the pivot axis is first placed in the plane A-B. The correction found in this set up is placed permanently in the balancing plane F-F. Then the pivot axis is moved to the plane C-D while the correction for the plane E-E is obtained. If this correction were applied directly it would distort the first result around A-B. Therefore, the new weight must be distributed to both planes, so that the equilibrium around A-B is maintained. If all weights are applied at the same radius and the correction obtained in the second operation

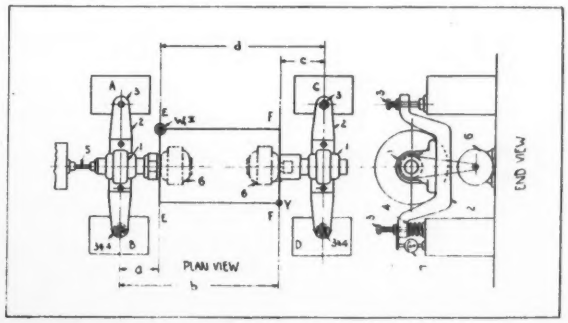


FIG. 3. SKETCH OF TURBINE ROTOR MOUNTED IN ORDINARY BEARINGS FOR BALANCING

is W, it is necessary to replace W, by two new weights, X in the EE-Plane and Y in the F-F plane on the opposite side of the rotor axis.

Then the requirement upon these weights are—

$$X\,d - Y\,C = W\,d$$
$$X\,a - Y\,B = 0$$

Which gives

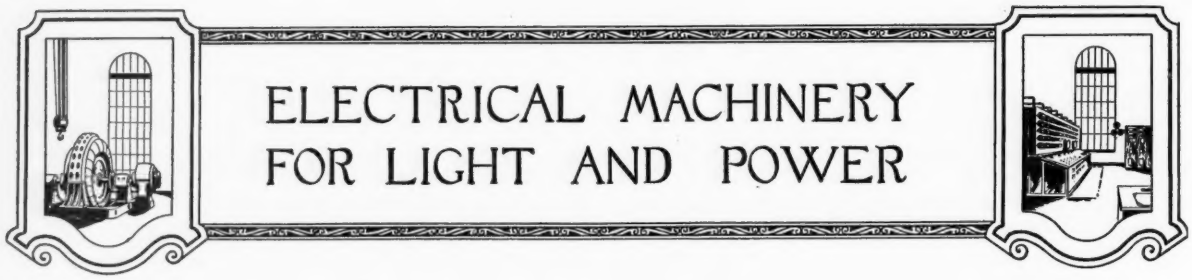
$$X = W\frac{W \times b \times d}{bd - ac}$$

$$Y = W\frac{A \times d}{bd - ac}$$

Thus the entire balancing is obtained by a minimum of three individual weights, as compared to two in the other arrangement. The sensitivity of this arrangement is slightly inferior to that of the arrangement in Fig. 1 and yet it is far beyond anything that can be obtained by ordinary methods of hand balance. This is shown by the extraordinary smooth operation of rotors balanced in this manner.

Definition of "Engineer"

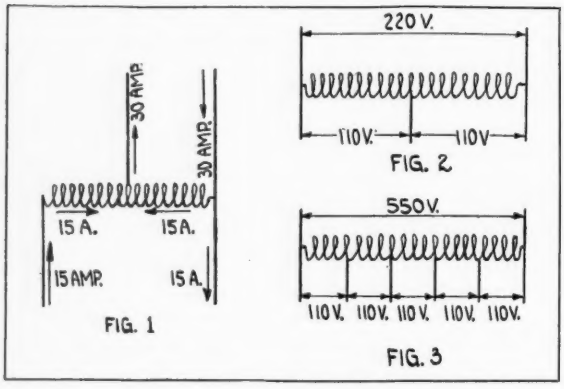
"THE engineer," said Marcus Vitruvius (B. C. 150), "should be a good writer, a skillful draftsman, versed in geometry and optics, expert at figures, acquainted with history, informed on the principles of natural and moral philosophy, somewhat of a musician, not ignorant of the sciences, both of law and physics, nor of the motions, laws, and relations to each other of the heavenly bodies. . . . Moral philosophy will teach him to be above meanness in his dealings and to avoid arrogance. It will make him just, compliant, and faithful to his employer, and what is of the highest importance, it will prevent avarice gaining an ascendency over him, for he should not be occupied with thoughts of filling his coffers nor with the desire of grasping everything in the shape of gain, but by the gravity of his manners and a good character should be careful to preserve his dignity."—Mechanical Engineering.



Operation of Converting Apparatus---VIII

PRINCIPLE OF THE AUTO-TRANSFORMER. METHODS OF CONNECTING TRANSFORMERS TO CIRCUITS USED IN COMMERCIAL PRACTICE. BY V. E. JOHNSON

IN THE DISCUSSION of transformers in the two previous articles* it was shown that the two windings of any transformer, that is, the primary and the secondary, are not electrically connected. For certain applications, however, where it is not essential that the windings be insulated from each other, an arrangement such as is shown in Fig. 1 may be employed. In this scheme part of the coils serve as both primary and secondary, and as the currents in these two circuits are in opposition the net current flow is their difference. Thus in the portion that serves both as primary and secondary, there are 30-amp. secondary flowing in one direction, and 15-amp. primary in the opposite direction, making a resultant load of 15 amp. This arrangement is called an auto-transformer. These devices are used extensively in many lines of electrical work and their use results in a considerable saving in first cost, particularly in the case of low ratios. The saving increases as a ratio of 1/1 is approached. On high voltages the saving is not so pronounced for here a great portion of the cost is made up of the insulation.

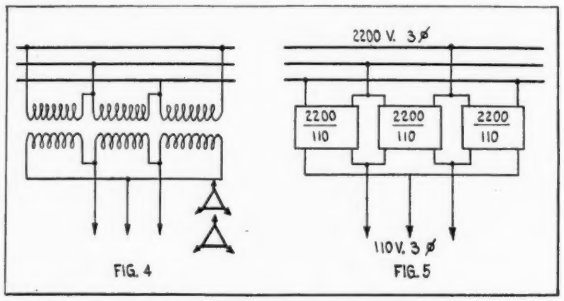


FIGS. 1-3. SIMPLE DIAGRAMS SHOWING PRINCIPLE OF THE AUTO-TRANSFORMER

Auto-transformers have numerous applications, the most common being that of supplying low voltage for starting motors. They are used as balance coils on three-wire systems, and are also used in connection with low-voltage rectifiers.

In common with two-coil transformers, the ratio of auto-transformers is determined by the relative number of coil turns in the primary and secondary circuits. This ratio is affected by load conditions just as in the previous case, while the losses occur in an analogous manner.

Figure 2 shows schematic connections for 3-wire balancer service, while in Fig. 3 is shown the arrangement for 5-wire use. The latter is, however, not in common use, as it imposes too high a voltage on the lamp connections,



FIGS. 4-5. SHOWING METHOD OF CONNECTING SINGLE-PHASE TRANSFORMERS FOR 3-PHASE SERVICE

and is apt to cause a breakdown. There is also some personal hazard present.

TRANSFORMERS ON POLYPHASE CIRCUITS

Ordinary single-phase transformers may be used on polyphase circuits, or, in their stead, polyphase units may be utilized. Figure 4 shows the schematic connection of three transformers on a three-phase system. Figure 5 shows how the leads would be brought out of the tanks and connected to the lines. The arrangement in Fig. 4 is called "delta" primary to "delta" secondary or more briefly "delta-delta."

Figure 6 shows a number of other connections, each having the name indicated. They are self-explanatory as far as the arrangement of the leads is concerned but there are certain outstanding points in connection with each that must be considered.

The delta-delta connection is a common one. In it the full line voltage is impressed across the terminals of each transformer primary, while the secondary voltage is equal to the voltage across any transformer secondary. If one transformer burns out it may be cut out of service, and power continue to be taken from the remaining two units as in Fig. 7. When this is done, the capacity of the combination is less than 2/3 of the three units, being in the neighborhood of 57 per cent. There is also a tendency to unbalance the circuits.

*Operation of Converting Apparatus VI and VII in the Feb. 1 and March 1 issues respectively.

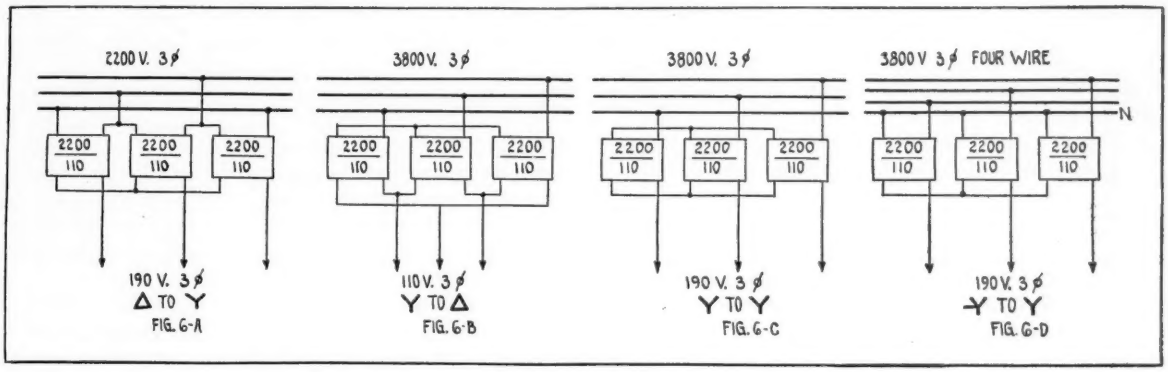


FIG. 6. VARIOUS TRANSFORMER CONNECTIONS USED IN PRACTICE

Often the delta-star connection is used in connection with high-tension systems where the current is generated at a low voltage and brought to the transformers in delta, and then stepped up to high tension in star. The advantage of this is that each high voltage winding need be

only $\frac{1}{1.73}$ of the high side line pressure.

The star delta connection is exceedingly common on so-called three-phase, four-wire systems. It is not advisable to connect the neutral of the transformer bank to the neutral of the generator for the following reasons:

a. Such a connection permits the so-called "third harmonic current" to circulate between the generator and the transformer bank. This overloads the latter, and wastes station capacity.

b. A bank so connected tends to balance the loads on the primary system. The result is that a small bank may burn out due to the unbalanced primary phase loads. On large banks of transformers this balancing effect does not make much difference, and it is quite usual to find station transmission line banks so connected.

The star-star connection cannot be used unless the primary neutral be connected to the generator neutral. If this is not done the neutral will "shift" so that the phase voltages will become greatly unbalanced.

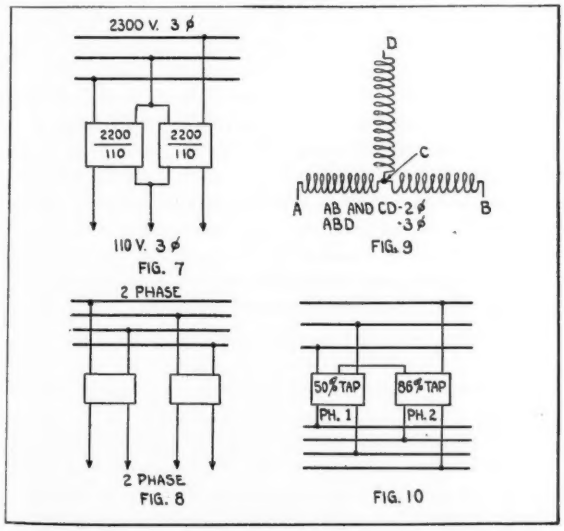
For use on two-phase systems the arrangement is as in Fig. 8. This is nothing more nor less than two single-phase lines as far as the connections are concerned.

To transform from three-phase to two-phase or vice versa a scheme of connections such as that in Figs. 9 and 10 are used. The former is used where there is no change in voltage so that auto transformers may be used, while the latter shows two coil transformers which may change the number of phases and at the same time step the voltage up or down.

Six-phase power for use on the rings of rotary converters may be obtained by several different connections. Figure 11 shows the connections for transforming two-phase to six-phase; Fig. 12, the methods of changing three-phase to six-phase.

Polyphase Transformers

Mention has been made in a previous paragraph of polyphase transformers. These are essentially three single-phase units inclosed in one tank, and having star or delta connections as the application requires; however, they are cheaper than the same capacity in single phase units, because certain portions of the magnetic circuit are made common to all three.



FIGS. 7-10. MORE TRANSFORMER CONNECTIONS

Fig. 7. The Open-Delta Connection Is Often Used in Case One Transformer on a 3-Phase Bank Burns Out. Fig. 8. Two Transformers Connected to a 3-Phase Circuit. Fig. 9. Schematic Diagram Showing Phase Transformation. Fig. 10. Actual Method of Connecting Transformers for Phase Transformation.

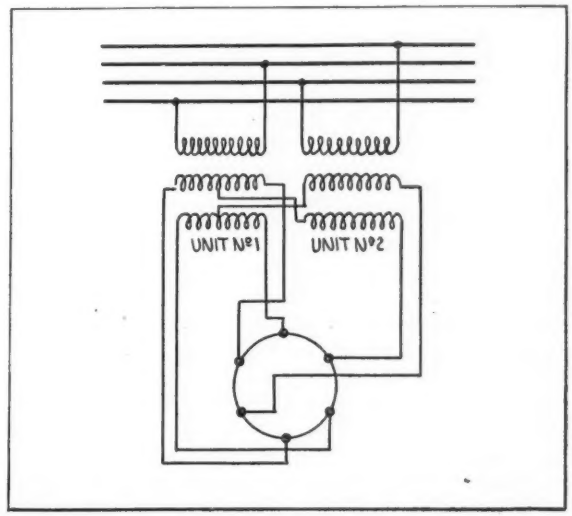


FIG. 11. CONNECTIONS FOR TRANSFORMING FROM 2 TO 6-PHASE

With delta-delta connections on three phase transformers it is possible to operate with one phase winding damaged. This is done by disconnecting it from the primary and secondary lines, and shortcircuiting the damaged windings upon themselves.

Polyphase transformers may be made with tertiary windings, and with taps and series parallel arrangement of

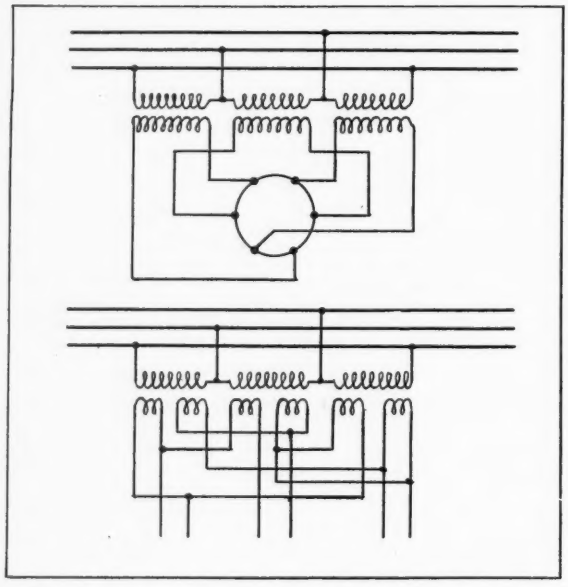


FIG. 12. METHOD OF CHANGING FROM 3 TO 6-PHASE

the coils. Auto-transformers may also be made three phase.

MECHANICAL CONSTRUCTION OF TRANSFORMERS

An ideal transformer would have the following features:

a. Freedom from operating hazard. This is brought about by providing sufficient barriers between the primary and the secondary.

b. Rugged construction so as to reduce maintenance to a minimum.

c. High efficiency.

d. Low first cost.

Obviously there is no one standard arrangement of coils and iron which will meet these conditions throughout the vast range of loads and voltages. As a result, there are a variety of designs each particularly suited for some specific class of work. These may, however, be divided into two main classes—shell type and core type. There are also a number of designs which are in a sense a cross between these two. Principal among these is the distributed shell type. This is commonly applied to small sizes of distribution transformers operating at 2300 v. and less.

Large transformers are frequently cooled by means of water coils immersed in the oil. A watercooled transformer is, generally speaking, considerably cheaper than a self cooled unit, and occupies less space but on the other hand it requires a continuous supply of cooling water which may under various conditions be undesirable. If the water supply fails, the transformer will burn out, as many of them cannot operate even at no load without external cooling. In order to prevent an accumulation of moisture in the oil due to sweating of the pipes which carry the water, these are carefully insulated above the oil level.

MAINTENANCE AND INSPECTION

There is little maintenance expense about a transformer, as it has no moving parts and nothing to wear out. Attention must, however, be paid to the following points:

a. Load. A transformer should not be overloaded, as this will cause rapid deterioration of the insulation and also cause a gradual breakdown of the oil. In order to avoid this, it is desirable to equip each unit with some device for indicating the temperature or the load, the former being the most logical. These temperature-indicating devices may consist of little thermostatic semaphores which show a "flag" when the safe temperature has been exceeded, or of gage type thermometers with maximum indicators and alarm bells. There is a considerable variety of this class of apparatus available, some of it costing very little, so that there is little reason for going it "blind" on the load conditions.

b. Lightning. Although the end turns of a transformer are heavily insulated so as to withstand abnormal voltage surges, it is poor practice to permit all such strains to be impressed on the apparatus. Lightning arresters should be provided so as to relieve these stresses before they reach a dangerous value. For small transformers there are available a variety of reliable arresters, and their use is good insurance against interruption.

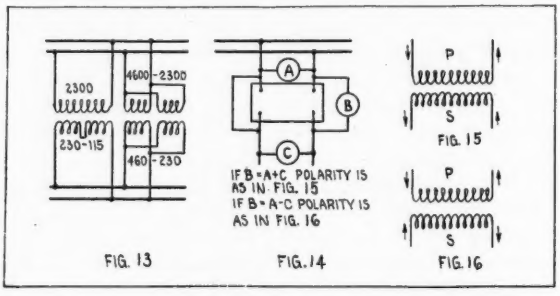


FIG. 13 FIG. 14 FIG. 15 FIG. 16

FIGS. 13-16. ILLUSTRATING PRINCIPLES USED IN CONNECTING TRANSFORMERS IN PARALLEL

c. Location. If transformers are located indoors, care should be taken that sufficient ventilation is provided so that they remain cool within the temperature rating guarantees. This does not apply to water-cooled units, as these can be closely confined. With these there should be a visible indication that the water supply is uninterrupted.

d. Oil. Oil must be kept dry and clean. There is a tendency for oil to sludge due to decomposition when in contact with the air. In newer designs this is largely eliminated by the use of auxiliary expansion tanks which present a comparatively small area of oil surface to the action of the atmosphere and which have sumps provided so that the sludge that does form is kept out of the main transformer tank. Another still later design uses an inert gas above the top of the oil in the tank, and so not only effectively prevents sludging but also leaves a cushion above the oil to take care of sudden oil displacements.

There is a tendency for moisture to accumulate in the oil. This is sometimes present in large quantities and can be drawn off through pet cocks at the bottom of the tank; however, if water is present in such quantities it is unwise to continue the operation of the unit until the oil has been replaced or filtered. Large companies test the oil in their larger transformers periodically and filter the oil as soon as it shows evidence of moisture or dirt.

This filtering can be done with the unit in service by pumping the oil from the bottom of the tank and discharging it from the filter into the top.

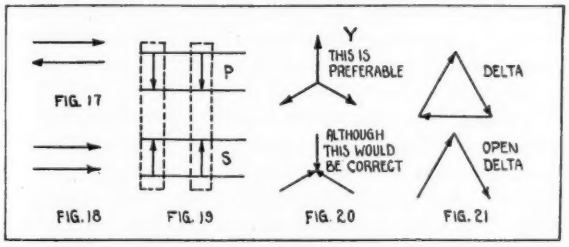
The filters for this kind of work consist of two main classes. One of them passes the oil to be purified through blotting paper which removes the dirt and absorbs the moisture. The other type operates on the principle of the cream separator and removes the water and impurities by a centrifugal action.

While the testing of oil is essentially a simple process, consisting of nothing more or less than finding the breakdown voltage between electrical contacts separated by specific distances, yet there are so many factors that tend to affect the results and so make them inaccurate that all such work must be carefully done. Several samples should be tested, and care should be taken that the following sources of error are eliminated:

a. Air bubbles in the oil make considerable difference. The oil should be stirred gently and then left to stand so that all air which may have become entrained will have a chance to pass off.

b. Tests of the same sample should not be repeated in too rapid sequence as this will give false results.

c. Care must be taken that the points, balls or discs used as test terminals are of the proper size, and that the voltage tests are those which correspond to the particular test outfit in use. Thus a change in the diameter of the test discs will make a difference in the breakdown voltage



FIGS. 17-21. METHOD OF REPRESENTING DIRECTION OF CURRENTS IN TRANSFORMERS WHEN CONNECTING THEM TOGETHER

obtained, while the use of spheres instead of discs will give another set of results. The plane in which the test surfaces are placed also varies the voltage values obtained.

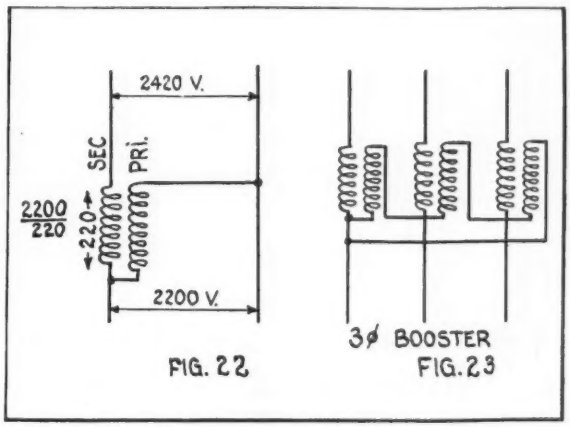
It is therefore essential that the testing procedure outlined by the manufacturers of the testing apparatus be followed minutely. If possible the transformer provided by them for such purposes should be used, in order that no error due to wave shape may be introduced. This is, however, a refinement that will usually be unnecessary, as any well designed transformer of sufficient capacity should give results accurate enough for practical purposes.

Typical Connections

There are a great variety of transformer connections, and it would be impossible to list them all. There are, however, some fundamental principles involved, and some convenient "rules" which will solve most of the problems which will be met.

When dealing with several units which are to be connected in parallel or in any of the various polyphase arrangements, the first thing to determine is that they are all connected so as to give the same terminal voltage. This information as to connections is obtained from the name plate readings and sometimes from diagrams which are attached to the transformer case or cover.

Example: Two transformers, one having a ratio of 2300 to 230-115 and the other a ratio of 4600-2300 to 460-230 are to be connected in parallel. A little consideration will show that the only primary voltage common to both is 2300 and that to obtain this on the second unit its



FIGS. 22-23. SINGLE AND THREE-PHASE BOOSTER CONNECTIONS

primary windings must be placed in parallel. Similarly the only common secondary voltage is 230 and to obtain this the first unit would have to have its windings in series, while the second would be in multiple. This would give a ratio for either one of them of 2300 to 230. Figure 13 shows how these would be connected.

Having connected the units so as to have the same ratio, the next step is to determine the polarity. For single-phase service this has already been explained. In order, however, to establish the direction of current flow for future use it is well to make a test as indicated in Fig. 14. In this the primary and secondary leads on one side of the unit are connected together and readings taken between the other two terminals—one of which is the primary and the other the secondary. If the voltage across these latter terminals equals the sum of the primary and secondary, then the instantaneous polarities are as indicated in Fig. 15. If the reading is, on the other hand, the difference between the primary and secondary voltages the instantaneous polarity is as in Fig. 16. Having made these tests, it is easy to indicate the primary and secondary coils by means of arrows, so that Fig. 17 would represent the condition in Fig. 14 and Fig. 18 that of the other arrangement. These symbols are of course arbitrary but they assist in laying out the connections.

Having resolved each unit under consideration into an arrow whose direction indicates the polarity, the next step is as follows: For parallel operation with the tails of the arrows together on the primary the tails of the secondaries must also be together. See Fig. 19.

For three-phase star the arrows should be as in Fig. 20, while for delta the connection would be as in Fig. 21. Applying these arrows to the schematic connections in Fig. 6, any desired combination can readily be obtained.

Figure 22 shows a special application known as a booster connection. The primary is connected across the line, while the secondary is in series with the line. For one connection the secondary voltage is added to that on the primary side, hence it is called "boosting," while the opposite connection subtracts the secondary from the line hence it is "bucking." The figures marked in the sketch indicate the voltage values obtained. Any standard trans-

former may be used for this connection but the following precautions must be observed:

a. As the secondary is connected to the high voltage lines, it must be insulated from the ground by some such means as mounting the case on a marble slab. This in turn introduces a considerable hazard to the operators, as the tank may have full voltage on it.

b. A boosting transformer cannot be disconnected from the line while the current is on, without the use of special precautions. If the secondary is short-circuited, the result is the same as on any transformer. On the other hand, if the primary is disconnected with the secondary in series with the line, a high and destructive voltage will be set up across its terminals.

On a three-phase circuit the booster transformers would be connected as in Fig. 23.

Obtaining Reduced Voltage Without Use of Taps

By F. C. DeWeese.

ON A LARGE system, where the writer is employed, it recently became necessary to filter the oil in several transformers, ranging in size from 100 kv.a. to 1000 kv.a.,

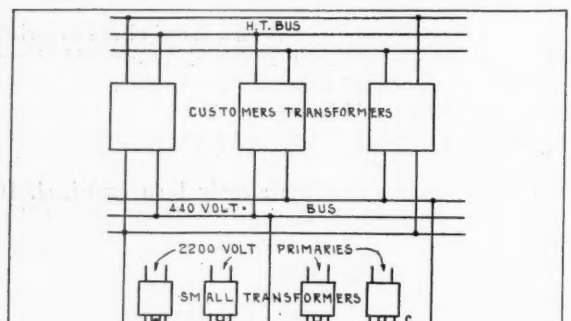


FIG. 1. DIAGRAM SHOWING USE OF FOUR 2200/220/110-V. TRANSFORMERS CONNECTED ACROSS 440-V. LINE.

the greater number of these transformers having 440-v. secondary connection. A large majority of the transformers were of the newer type, having the voltage taps inside of the case, for changing from 440 to 229 v., thus making it impossible to make any changes without taking the transformers out of service, which was not practical.

As there were not available transformers with 440-v. primary windings and as it was necessary to have 220-v. service for the filter press motor and drying oven, the following method was resorted to.

Four small standard distribution transformers with 2200/220/110-v. windings were connected with the secondaries of two transformers in series across the 440-v. buses of the large transformers, the connections being made to points A, B and C, Fig. 1, making the equivalent of two 440-v. transformers connected in open delta. The connection to the 220-v., three-phase motor was taken from points D, B and E, thus giving 220-v. three phase service. The 110-v. service for the oil testing transformer was taken from points A and F. The 2200-v. leads of the transformers were coiled up and taped, to avoid any injury to anyone who might come in accidental contact with them.

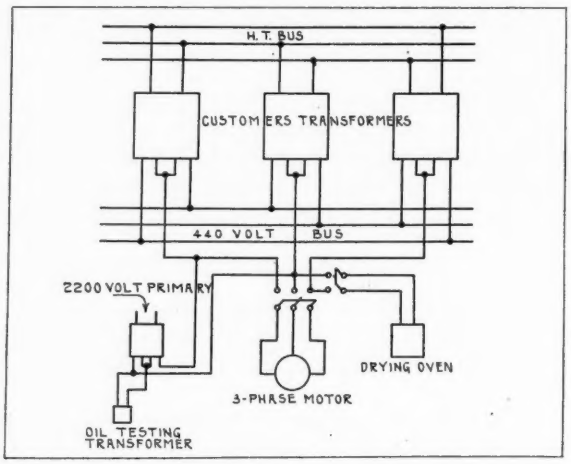


FIG. 2. SHOWING USE OF TRANSFORMERS WITH 4 LEADS ON 440-V. SYSTEM

Where four leads were brought out of the transformers, the 220-v. filter press motor was connected to the middle taps of the windings, as shown in Fig. 2, one small transformer, in this case, being connected as shown at the left hand side of Fig. 2, for obtaining service for the oil testing transformer.

In some few cases, 220 v. was available from the customers' premises, but for two reasons it was not used: First, it would be necessary to make the connections on the load side of the customer's meter, thus consuming energy which the customer was paying for. While most customers would not object to this, it was not considered advisable to take this advantage. Second, in most cases it would necessitate the running of considerable wire from the available 220 v. to the motor and oven, thus adding to the time and expense of the job.

Acknowledgment

In March 1 issue of Power Plant Engineering, on page 275, was published "Results of a Series of Evaporative Tests at the River Rouge Plant of the Ford Motor Company." By oversight, statement was omitted from the article that these were tests made at the plant and reported on by Martin Frisch, Victor F. Murray, and Robert E. Ekins, of the Research Department of the Combustion Engineering Corporation.

Correction Note

We wish to direct attention to an error in the article, Practical Application of Hydraulic Principles—I, which appeared in the February 1, 1925, issue. In the formula at the bottom of the first column, page 189, $Q = A_1 \times V_1 = (3.14 \times 9 \div 4) \times 10 = 0.49$ cu. ft. per sec. the area of the pipe, i. e., $(3.14 \times 9 \div 4)$ is given in sq. in. whereas the flow is given in cu. ft. per sec. Naturally, this is incorrect. The area of the pipe should be expressed in sq. ft. in order to give Q in cu. ft. per sec. The formula therefore should read $Q = A_1 \times V_1 = (3.14 \times .25^2 \div 4) \times 10 = 0.49$. The answer 0.49 cu. ft. per sec. is correct.

Electrical Measurement of Physical Values

MEASUREMENT OF TEMPERATURE AND MEASUREMENT OF FLOW IS ACCURATELY ACCOMPLISHED BY ELECTRICAL METHODS

ONE OF THE most interesting papers presented at the recent Midwinter Convention of the American Institute of Electrical Engineers held in New York City in February, was one by Perry A. Borden on the measurement of physical values by electrical methods. The paper was prepared under instructions from the committee on Instruments and Measurements with a view of forming a basis for the Committee's work in connection with electrical measurements as applied outside of the strictly electrical field.

It is impossible in this abstract even to touch upon all of the various subjects treated in Mr. Borden's paper and no attempt will be made to do so. Of the various classifications listed, the two that will be considered and that will be probably of greatest interest to power plant engineers are those concerned with the measurement of temperature and of flow.

MEASUREMENT OF TEMPERATURE

Until late years the importance of accurate temperature measurement seems to have been overlooked by many branches of industry. Recently, however, there seems to have been an awakening to the importance of accurate temperature determination, with the result that there have appeared a large number of excellent temperature measuring devices.

Most electrical thermometers are based upon one or other of two principles, either the potential difference at a junction of two dissimilar metals maintained at a temperature differing from that of the rest of the circuit, a property discovered by Seebeck in 1821; or upon the change in electrical resistance accompanying change in the temperature of any pure metal.

In 1833, the thermopile was combined with the galvanometer by Nobili and Melloni to produce a temperature-measuring instrument of great sensitivity. In 1887, Boys greatly increased the sensitivity of this apparatus by combining the two elements in one instrument, so that the thermo-junction formed a part of the galvanometer loop, and swung with it in the field of a magnet. In 1881, Langley contrived another instrument of very great delicacy for measuring radiations, which he called a bolometer. This consisted of four very fine platinum or iron wires, forming the arms of a Wheatstone bridge connection. Alternate strips were exposed to radiation, and a measurement made of the unbalance of the bridge due to changes in the temperature (and consequently of the resistance) of the arms. The thermo-galvanometer of Boys was estimated to indicate the one hundred-millionth of a degree, while the bolometer was capable of about one-tenth of that sensitivity.

In measurements embodying the use of the thermo-electric principle, it is usual to place one couple in as close association as possible with the body under measurement, and the "cold junction," necessary to complete the circuit, in a location where its temperature can be conveniently determined or regulated. The voltage set up in the circuit is then a measure of the temperature difference between the junctions, and therefore of the temperature of the "hot junction." Measurement of this voltage may be directly made with an instrument of the d'Arsonval type, or it may be performed with a potentiometer, which may be either indicating or recording. Where the direct deflecting instrument is used, a current in proportion to the measured voltage will flow through the circuit; and this, by the Peltier effect, will tend to equalize the temperature of the junctions, thus crowding the scale in its upper ranges. The selection of metals employed will vary with the conditions under which the measurement is made, depending upon the precision and permanency required, upon the temperature range through which the couple may be carried, and upon the possibility of corrosive effects in the atmosphere surrounding the thermo-junction.

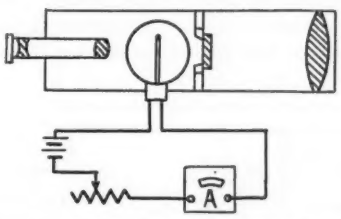


FIG. 1. OPTICAL OR DISAPPEARING FILAMENT PYROMETER

In one form of temperature-measuring instrument operating upon this principle, known as the radiation pyrometer, developed by C. Fery, the junction is not placed in direct contact with the heated body, but is used in combination with an optical focusing device, so that when a certain image of the incandescent surface is obtained in the telescope field, the exposure of the couple is such that the indication of an associated galvanometer is a measure of the temperature. Fery has also produced a bomb calorimeter of interesting construction, in which the steel body of the bomb is plated with copper and supported by two constantin disks. The change of temperature attendant upon combustion of the charge produces a thermo-electromotive force in the structure; and the value of this voltage is read upon a suitable galvanometer directly graduated in calories. An amplification of this principle is found in an isothermal calorimeter exhibited in 1924 by the Research Department of the Arsenal at Woolwich, England. The bomb or container in which combustion takes place is associated with a double set of thermo-junctions, one serving as a source of measurement and regulation, and the other, using the Peltier effect, to neutralize the temperature rise due to the combustion under measurement. The current in the Peltier junctions is regulated through the agency of the thermocouples, to maintain the temperature of the bomb constant within 0.0001 deg. C. and a measurement of this current furnishes a direct indication of the rate of heat evolution.

It is characteristic of all pure metals that they change their electrical resistance with changes in temperature; and this property has been widely used in measurement of temperatures. As a rule the detector employed in this class of work consists in a small coil of wire (usually copper, platinum or iron), forming one arm of a Wheatstone bridge, the remainder of the bridge circuit being at or near the point where the indication is required. As in the case of the thermo-electric system, the indicator may be either direct reading, in which the galvanometer in the

bridge circuit is graduated in thermal units, or the galvanometer may be incorporated in a zero-reading device, either indicating or recording. In either case the simplest arrangement is that embodying the direct reading instrument; but far greater accuracy and higher precision are obtained when zero methods are used. In determination of temperatures of small areas the thermo-electric method is usually the more satisfactory; while if the average temperature of a considerable mass or area is required, the resistance method is often the better. This is particularly evident in the determination of the temperatures of the windings of electrical apparatus. "Hot spots" are better located by thermocouples placed in proximity to the windings, while average temperatures of coils may be measured by closely associated resistance units or by direct measurement of the resistance of the windings themselves.

Another application of the electric current in temperature measurement is found in the optical pyrometer used in the determination of temperatures in the luminous range. Here the heated body or surface is viewed in contrast with the filament of an incandescent electric lamp, and the current through the latter adjusted until the filament disappears against the heated background. A reading is then made of the current, from which the temperature of the filament and consequently of the heated body may be determined.

Since both the thermo-electric effect and the resistance method are particularly suited to the measurement of temperature difference, use has been made of them in determining quantities which depend primarily upon this difference. A heat-flow meter dependent upon temperature gradient in a known mass, has been developed for study of boiler-room conditions; and a humidity recorder, depending for its action upon an electrical measurement of the difference in temperature of a wet and a dry-bulb thermometer, has recently made its appearance in several forms. Another form of hygrometer, lately exhibited in England, directly determines the percentage of moisture in the air by measurement of the dew point. Radiant heat from a small lamp falls upon a polished metal surface, whose temperature is regulated by a brine coil, whence it is reflected and focused upon a small thermo-junction in the circuit of a galvanometer. When dew forms upon the polished surface the thermo-electric current is reduced; and a distinct disturbance of the galvanometer indication takes place. The sharpness of indication and the essential simplicity of this apparatus makes its use highly desirable in hygrometric work, particularly at low temperatures.

Flow of both liquids and gases can be determined by a number of electrical methods; and several of these have become standardized in modern engineering practice. In liquid flow meters use is made of either the electrical conductivity or heat capacity of the fluid, or electrical measuring devices may be employed as auxiliaries in the determination of the pressure head developed by the flow of the liquid through an orifice or a Venturi tube.

A highly satisfactory means of determining the velocity of flow of water, particularly applicable to large conduits, such as penstocks, is found in Prof. C. M. Allen's recently developed "salt-velocity" method. There is injected into the penstock a quantity of saline solution, the presence of which has a marked effect upon the electrical conductivity of the water. The passage of the solution is detected by means of an electrode consisting of a pair of parallel plates projecting well into the liquid and connected in series with a detector circuit. A number of schemes have been used for determining, from the current flow across the electrodes, the velocity of the water in the pipe. One is to measure the time lapse between the injection of the salt solutions and the time of maximum conductivity between the electrodes situated a measured distance along the conduit, another employs two similar pairs of electrodes, and the time interval is taken between the instants of maximum conductivity at the respective stations. While the electrical readings may be obtained with ordinary ammeters, there has been developed an ingenious recording arrangement, wherein the record appears on a graphic chart as two series of dots from which the time interval may be scaled off at leisure.

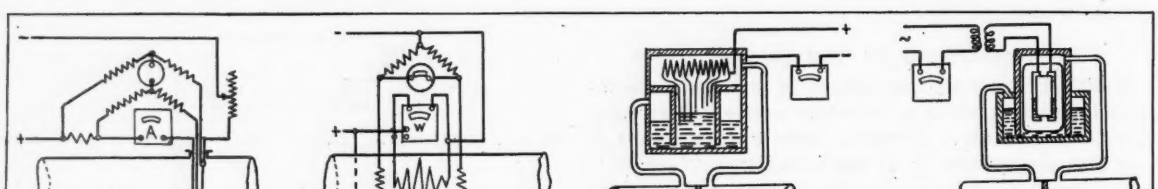


FIG. 2. KING GAS METER. FIG. 3. THOMAS GAS METER. FIG. 4. REPUBLIC FLOW METER. FIG. 5. G. E. FLOW METER

Experiments have been carried out with a view to establishing a definite relationship between the resistance to passage of an electric current between two electrodes and the velocity of motion of the water in which they are immersed; but in the present state of development, this relationship, while it unquestionably exists, has been found to be of too erratic a nature to justify its employment for flow determination.

A device designed particularly for measuring oil-flow in transformers consists in a very small ball of copper wire which is inserted in the pipe. This ball forms one arm of a bridge circuit, the other arms being varied in such a way as to maintain a condition of balance. By this means a determination is made of the number of watts necessary to keep the little ball at a constant temperature. Referring these values to a calibration curve, it is possible to read off the flow of oil in the transformer cooling system. A somewhat similar application is found in the Griffith's depth gage, used for measuring the amount of liquid in tanks. Here the radiating conductor takes the form of a straight slender wire reaching down into the liquid from above. A similar wire, parallel to the other, but shielded by a tube from actual contact with the liquid, serves to

compensate for changes in the temperature of the liquid. The cooling of the exposed conductor is proportional to its immersion, and the unbalance so introduced is read on a galvanometer or recorded by a graphic instrument. A device of this nature, used in connection with a calibrated weir forms an exceedingly convenient flow meter.

In the measurement of gas-flow a wide use has been made of the principle known as the hot-wire anemometer, in which a heated wire is exposed to the flow, and an electrical determination made of the cooling effect upon the wire. For most practical conditions the indications of the anemometer depend upon the product of density and velocity. In the meter developed by Dr. L. V. King, an electrically heated wire reaches across the pipe in which the measurement is to be made and means are provided for adjusting the current so as to maintain the wire at a fixed value of resistance. A measurement of this current gives the instantaneous value of the flow of gas, and the results may be obtained in an indicating, graphic or integrated form. A very similar device has been used to measure the air-intake or internal combustion engines.

The cooling effect of the gas stream is made use of in a somewhat different way in the Thomas gas meter, which is based upon the measurement of the amount of heat required to raise the temperature of the gas through a known range. Two similar resistance thermometers, forming two arms of a bridge are inserted in the main, and between these is placed a heating element. Both the heater and the resistance thermometers are well distributed over the cross section of the pipe. While this meter has a number of forms, its commercial arrangement is such that a constant temperature difference is maintained between the two resistance thermometers by means of adjustment of the current flowing in the heater, and measurement is made of the power represented by this heating current. The meter is made in a recording form, and may be made to read either in pounds or in cubic feet at any desired pressure and temperature.

The importance of knowing the amount of steam consumed in power plants has led to the development of a number of practical flow meters, which have now become standard equipment in all large steam-driven stations. The pressures, temperatures and velocities here met with prohibit the methods which are applicable to ordinary gas-flow measurements and recourse is had to the orifice or the Venturi tube. The pressure-head, so developed, may then be determined by electrical means. One of the best known is the Republic flow-meter, in which the U-tube normally found as an accessory of the Venturi meter is developed into a reservoir containing mercury, which, as it rises, short-circuits the ends of a number of vertical rods of different lengths forming the terminals of resistances. Changes in the mercury level thus serve to operate a rheostat, this rheostat forming a part of a circuit supplied from a source of constant voltage. Thus, the value of current flowing in the circuit depends upon the flow through the pipe, and by properly proportioning the resistance between rods, it may be directly proportional to the flow. The current may be made to actuate an indicator or a recording instrument; or, if desired, it may be passed through an integrating meter to produce a record of the volume of fluid which has passed through the pipe.

A development somewhat similar to the above is found in the flow-meter recently announced by the General Electric Co. In this, the column of mercury, instead of bridging the points of a rheostat, forms a short-circuited secondary to a small transformer. As the height of the mercury changes, the cross-section of the ring varies, and with it, the secondary conductivity. This produces a variation in the primary current which may then be measured by any of the standard methods for metering alternating current quantities.

Engineer's Responsibility in Fixing Charges

CHANGES SHOULD NOT BE MADE UNLESS WARRANTED. DEPRECIATION CHARGES GROW RAPIDLY ENOUGH WITHOUT HELP. BY LOUIS R. LEE.

WHEN SELLING electrical energy for light, power and heat, it has always been necessary to sell at low and uniform cost, although a great many of the elements that go to make up the costs are subject to price fluctuations. During the war period there may have been some advances in rates but generally the tendency has been downward and probably electric power is today one, if not the cheapest, of all commodities. Every electric power rate is influenced or determined by two factors, running charge and fixed charge. The running charge in a steam electric system is made up principally of fuel, labor, maintenance and distribution losses. Fixed charges are principally taxes, interest and depreciation. In a hydroelectric system there may be only a small percentage of steam generation and therefore a small item for fuel. The fixed charges, however, may be greater than in the steam electric system. Without going into all of the complexities of rate making, it is obvious and generally agreed that the two principal factors that influence rates are the fixed charge and the running charge.

The fixed charge is well named. It is fixed and the engineer that lays out the system and adds to it from time to time has much responsibility in determining this fixed charge. Every electric system has its plant property account. The plant consists of generating plant, distribution system, substations, transmission lines, customers' service, shops, real estate and office buildings. No system was ever purchased ready made, they grow up, their growth being influenced by the prosperity of the community in which they exist. The engineer who directs or fixes the characteristics of the plant must furnish information which will cause decisions to be made from time to time fixing the limits of the system. There are questions of frequency, transmission and distribution voltage, whether transmission lines are to be carried on wood poles or steel towers over private right of way or along existing roads, whether the lines are to be built in duplicate, to provide for future growth and how long old equipment is kept in service and made to function.

Any company to be successful must furnish an adequate and reliable supply of electric service. The growth in any community usually is not at a uniform rate but is more or less spasmodic, as communities grow unequally in different directions so that while the increase over a period of years may average fairly uniform, there is no assurance that it will be uniform in any one particular period.

Every engineer in considering the welfare of the company he is with must deal with two different departments which have considerably different viewpoints. First, there is the operating department which meets conditions from day to day, dealing with things that are real rather than theories. Second, there is the finance department which is also dealing with facts, however, it must have considerable foresight and must build up some net receipts.

Estimates of Costs Are Important

In considering extensions to plants and lines, the engineer must make estimates of the cost, calculate the efficiency of the proposed improvements, the efficiency being expressed in terms of dollars as well as thermal or other technical terms of efficiency. Both the operating department and the finance department have the best interests of their company in mind but the operating department, with trouble always fresh in mind, is apt to be influenced towards greater guarantees of continuity of service than the finance department which is a little farther away from the actual trouble which occurs from day to day.

It is the duty of the engineer to make thorough studies of all of the shortcomings of present facilities and to estimate and lay out all such improvements as could be reasonably considered, to eliminate or avoid the trouble experienced in the past. It is his duty to make as many alternate plans as possible so that all parties concerned can consider all different ways that improvements may be made. In considering new improvements, it is essential that full consideration be given to the latest improvements which have been made in the art such as new equipment, new methods of distribution, transmission and so on. In considering new improvements, study should be made to see how likely these new improvements will be permanent improvements and generally used. It is necessary to be up to date but it usually is just as unsafe always to adopt new ideas as soon as they come out as it is not to adopt them at all. It is always of extreme importance when making any new improvements to make a study to see how far this improvement may affect the whole system. It sometimes happens that comparatively small improvements have great influence on future plans. If in such a case, by making a small expenditure provision can be made so that later the change in the whole system can be made, it may be important to make such a provision.

Brief study will show that the fixed charge is of the greatest importance. No amount of good management can lower the cost of supplying electric service below the fixed charge plus a reasonable amount for operation. An expensive plant not only increases the fixed charge but oftentimes increases the running or operating charge. Therefore, the engineer and operating department must consider well and fairly every improvement and keep before them the total cost expressed in total and per kilowatt of capacity to be sure they are not establishing a fixed charge which will be a burden upon the system. Electric current, as stated in the foregoing, must be sold at a fairly uniform and low cost. It can not be sold at a low cost if the fixed charges are abnormally high, at least it can not be sold and allow a reasonable profit to be made.

In the design of the generating station, which is really the starting point of the plant, consideration of course must be given to the things which insure reliability and continuous service but the operating department must expect to assume certain responsibilities and to have only such equipment as is necessary to give good service. Elaborate layouts and over capacity out of proportion to load which is to be carried are factors which influence and cause high fixed charges. There have probably been fewer mistakes made in installing insufficient capacity or facilities than in installing too much.

Practically all power plant equipment is showing great improvement from year to year, therefore, if a plant recently installed becomes over loaded there is always an opportunity to purchase and install improved equipment to take on the increased capacity. If in making the design, larger capacity is installed than required, it may be necessary not only to pay the fixed charge on this surplus capacity but the company finds itself in a position of being unable to take advantage of improvements. It is well in considering surplus capacity to consider what parts of the plant are the least liable to be improved upon. There is some equipment which has greater flexibility than others. For example, there is the matter of transformers. There is probably no equipment in any system today which can show a better record than transformers considering efficiency, reliability and depreciation. As systems increase in capacity transformers that were originally used at generating stations or substations become relatively smaller and are moved along to the smaller substations or to customers' installations. Practically all transformers have some possibility of reconnection to allow for a change in voltage or for line drop.

Motors are also a class of equipment having considerable possibility for being reused under different conditions with small loss due to the change in duty. Therefore, it probably would be less costly to have provided an overcapacity in transformers or motors than in some other equipment. A careful study of a system will often show that some part of the system has had much less expended on it in proportion to the load carried than the remainder of the system.

For example, a system can be divided up into three parts, generation, transmission and distribution. It would be impossible to state just how much capacity each one of these departments should have in proportion to the load but it is obvious that there should be some uniformity in the additions to these different departments from year to year as the load is taken on. It would not be reasonable to double the capacity of the generating stations without increasing the other departments at all, that is, unless the other departments had already been developed out of ratio to the whole system. In the same fashion each one of these departments can be further subdivided to see if they are out of proportion to the load carried. For example, in the generating station we might find a liberal allowance for turbo generators in proportion to the load and a scant margin on boiler plant equipment.

Money Should Not Be Spent Uselessly

In considering all of these questions of improvements, ratio of capacity of equipment to load carried, it is the duty of the engineer to get all of this data together with the costs and consider it in making his improvements. It is his duty to keep before him all the time the fact that the company is in the business of selling electric current at a low and reasonable cost. Beyond a certain point elaborate buildings, expensive plant arrangements, special equipment, all has little value. The current generated by one power plant is no better than the current generated by

some other power plant. The main question is, after the question of reliability of service is taken care of, what is the cost of the current?

In considering efficiency it is obviously foolish to try and reduce the fuel bill if in so doing the fixed charge is increased by a greater amount. In the same way in considering water power versus steam; water power that will cost more than steam when fixed charges and running charges are considered is of no value. It is, of course, desirable to the community as a whole that as much water power as possible be developed so that we may conserve our natural resources of coal as long as we can but no community is willing to pay for the high cost of developing poor water power sites simply because of this idea of developing water rather than steam. In most localities the steam and water power combination make the best and lowest cost service. This is due to the fact that little water power can be developed which is constant in output. It varies from year to year and throughout the year depending upon weather conditions. A small amount of steam can be used in the average year, a greater amount being used in the lean water power years so that the cost or the fixed charge of the water power is not excessive in the average year. In practically all water power developments the fixed charge will be higher than the fixed charge of a steam electric system but offsetting this the running charge of the hydroelectric system will be proportionately lower and more uniform as it is influenced by fluctuations from year to year.

Avoid Peculiar Arrangements

First costs are often increased by special equipment and peculiar arrangements. The engineer has no right to impose high costs on to a system, in order to carry out some hobby. For example, suppose treated wood poles are available in lengths of 35, 40 and 45 ft. with, say, 8 in. tops. An engineer makes a study and considers that they should buy poles exactly 37.5 ft. long with 9 in. tops. The pole companies are asked to quote and naturally offer their standard sizes as carrying their best prices. The special pole would be hard to obtain and would cost much more than would the 45 ft. standard. Is it worth while and is it good economies for the engineer to try to set his own standard? The writer believes not. Further, it is his duty to prevent as far as possible and reasonable someone else, such as some municipal authority trying to establish a new standard. Standards are hard to get and not as common as we would like to have them. We don't want standards to prevent progress but we do want them where they may decrease costs, facilitate quick deliveries and rapid construction. There is a further phase of this question of costs that may be greatly influenced by the engineer, that is, depreciation and obsolescence. The electrical art has changed and is changing rapidly as systems grow and become larger in capacity, and again as systems become interconnected considerable equipment falling in the switchboard class in particular becomes obsolete. Oil circuit breakers, current transformers are especially vulnerable to obsolescence due to increased capacity. The engineer will be negligent if he fails to keep his system properly and adequately equipped with protective apparatus.

There is, however, a vast difference between going ahead and installing all new switchboard equipment relegating the old to the scrap heap and working over or moving old apparatus to less important positions. There comes a time when some piece of equipment may have reached the end of usefulness and it is wisdom to recognize such a condition when it arrives but it is the duty of the engineer to be sure of his ground before he consigns physically good apparatus to the scrap heap. The item of depreciation grows rapidly enough without help. A piece of equipment should be just as highly regarded if 10 yr. old, as if 1 yr. old, provided it is adequate for the service. The engineer must be without prejudice because of age, shape or design.

Oil Power Reduces Costs in Ice Cream Plant

Use of an Oil Engine as Main Source of Primary Power with Central Station Supply as Supplementary Proves Economical

EVEN BEFORE the days of the ice cream cone with its ever present allure for young America, the crowning feature of an outing was ice cream. The joy was somewhat dimmed, however, by the strenuous effort needed to get it ready, for, in addition to the frequent difficulty in getting ice, was the muss of preparation of the freezing mixture and the long steady grinding of the freezer which, especially if an amateurish job of packing had been done, reduced one's arms and back to pulp. Far different the modern process of smoothly running, power-driven machines which turn out gallon upon gallon of rich toothsome dainties by the closing of a switch. Yet such a process requires no small amount of power where the manufacture is on a considerable scale and it is necessary to watch power costs closely, if the maker is to realize the profit for which he hopes.

In the Mansion House Ice Cream Co. of Boston, one man has been responsible for the design and installation of the manufacturing and power plants. So successfully did Karl Wegemann plan, that but little alteration has been needed, as the plant has been enlarged to meet the requirements of growing business. Plenty of room for growth was provided when the building was erected and as new methods have been adopted and improved apparatus installed, the space allowed for extensions has proved adequate.

Capacity for freezing and hardening 1500 gal. a day and for making 15 T. of ice was at first installed. This called for 40-ton and 30-ton belt-driven compression outfits with auxiliaries, the power being obtained from the Cambridge Electric Light Co. During the winter of 1920-21 a 50-ton compressor was added and in Nov. 1922 a 150-hp. Ingersoll-Rand solid-injection oil engine was installed. This gave a total capacity of 120 tons refrigeration and a connected load of 440 hp. of motors, 205 hp. being in small squirrel cage motors, 125 hp. in slip ring motors for the smaller compressors and 110 hp. a direct-connected synchronous motor for the larger compressor.

In October, 1922, the load and cost of power were 53,407 kw-hr. and $1573.36 respectively, while in November, the oil engine being put in service on the 9th, the power from engine and central station was 31,118 kw-hr. and cost was $703.08. Of this, the engine furnished 12,600 kw-hr. at a cost of $75.60 and the central station 18,518 kw-hr. at

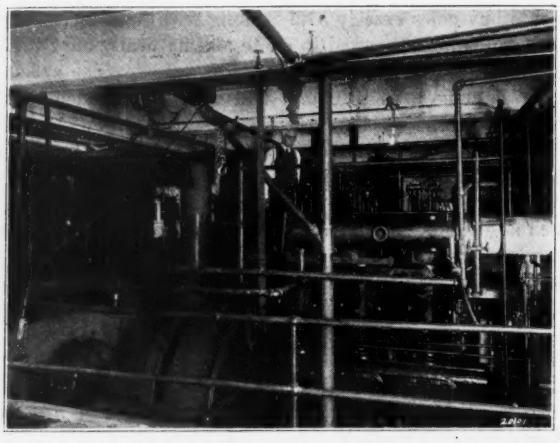


FIG. 1. 150-HP. SOLID-INJECTION OIL ENGINE WITH DIRECT DRIVE TO A.C. GENERATOR AND EXCITER

a cost of $627.48. Compared with Nov., 1921, when the output of the plant was practically the same, this showed a saving of $183.49.

After the engine was in regular service, a new form of auxiliary power contract was made with the electric light company at a higher rate but, in making cost comparisons, the kilowatt-hours used have been reckoned at the old lower rate and the engine charged with the increase in current cost due to the new rate. The new contract calls for a minimum charge of $2 a month per kilowatt of greatest possible demand, this demand being limited by fuses under lock and key which can be replaced only by employes of the light company and 60 days' notice in writing must be given of a change in the "demand." This maximum demand was set at 100 kw. for Nov. to April, inclusive, and at 200 kw. for the other six months, which necessitates a use of 5533 kw-hr. a month in the winter and 14,240 kw-hr. in summer to take care of the minimum charge of $200 and $400, respectively. In summer this is easy for the demand runs as high as 140,000 kw-hr. a month, of which the engine can furnish 90,000; but in winter it is necessary to use as nearly as possible 5500 kw-hr. a month, letting the engine carry the balance. Thus in Jan. 1924, the central station supplied 5550 kw-hr. of power and 968 kw-hr. of light and the engine 33,770 kw-hr., the total cost being $501.55 or $0.01244 a kw-hr., while for May 1924 the station furnished 21,000 kw-hr. of power and 1730 kw-hr. of light, the engine furnishing 75,280 kw-hr. at a total cost of $1265.44 or $.0129 per kw-hr.

Separating the costs of central station current and engine power, Mr. Wegemann gives the figures of $0.00605 per kw-hr. for engine power and of $0.0286 for central current in July 1919 at the old rate, of $0.343 in Jan. 1919 at the old rate, of $0.356 in May 1924 at the auxiliary rate and of $0.046 per kw-hr. in Jan. 1924 at the auxiliary

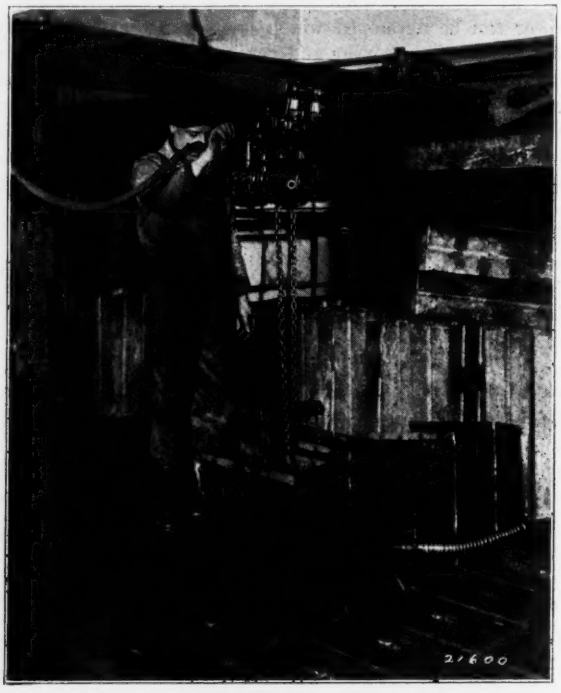


FIG. 3. ICE IS DRAWN FROM THE TANKS BY A CHAIN HOIST

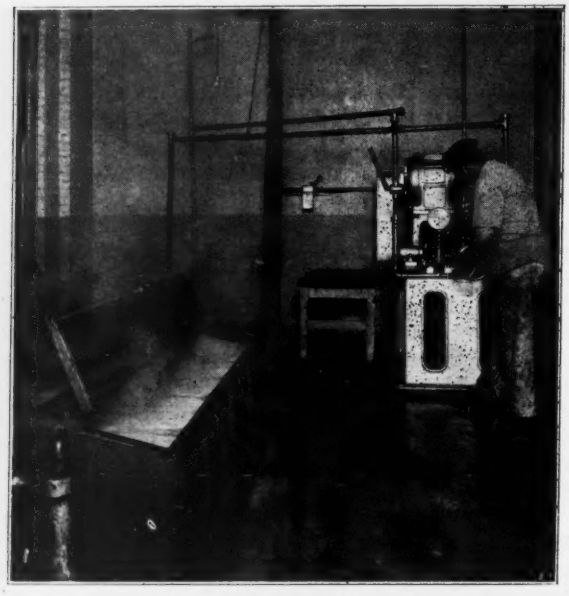


FIG. 2. REVOLVING, MOTOR-DRIVEN STEAM COILS STERILIZE THE INGREDIENTS OF ICE CREAM AT 140 DEG. F.

rate. It should be noted, however, that the central station rate is due to power rates of $0.023 and $0.0275 for current used for motors and of $0.0815 and $0.085 for current used for lights. From 1914, when the plant was started, up to 1922 when the engine was installed, the rate per kw-hr. ran for a yearly average from $0.0211 to $0.0340. For the years after the engine was in use, the cost for engine power ran for 1923, $0.0067 and for 1924, $0.007 per kw-hr. as a yearly average. In the same years, the cost for station current ran $0.0368 for 1923 and $0.0337 for 1924. The output during these years was in 1923, 493,400 kw-hr. for the engine and 254,962 kw-hr. for station power; in 1924, 555,020 kw-hr. for the engine and 338,168 for the station.

To make a comparison of the performance of the plant with and without the engine, a rate of $0.027 was used for station power, this being the average rate for the six summer months of 1922 and lower than the yearly rate for 1922. Assuming that all power had been purchased at this rate during 1923 and 1924, Mr. Wegemann states that

the saving for 1923 was $8294.77 and for 1924, $8092.77, during which time, $956.12 was charged to the engine for repairs and spare parts. Cost of the engine installation was: For the engine and generator, $16,200; for freight, cartage, rigging and erection, $800; for alteration to building, $2000; for foundation, $500; for switchboard and wiring, $1000; for exhaust and water piping, $500. The total saving for the two years was $16,387 and the total cost of the plant, $21,000, so that only $4612.46 has to be earned during 1925 entirely to pay for the plant.

In this comparison, no attendance charge was made against the engine as changes in the rest of the plant did away with much of the labor in the boiler room and this was allowed against engine attendance. No interest was charged on the investment, nor was depreciation figured, but upkeep and repairs, to the least detail were charged to operating cost, and the engine has been maintained in condition equal to new. Taxes and insurance at 2 per cent on $21,000 would amount to $420 a year which might rightly be charged against the engine plant.

Oil first used was 4.25 cents a gal. with added charges of 1.05 cents for freight, 0.5 cent for cartage and 0.2 cent for wastage, bringing the cost up to 6 cents a gal. at the plant. After July 1923, oil was 5.35 cents at the siding with supplementary costs which brought the cost in the plant tank to 6.05 cents. From June 1924 the cost in the tank was 6.8 cents a gal. Tests of oil consumption showed 0.437 lb. per hp.-hr. in Nov. 1922 at 121.8 hp. After adjustment to bring the engine up to full power, a test showed 0.463 lb. per hp.-hr. at a load of 101.6 hp. With further adjustment, the consumption was reduced to 0.413 lb. per hp.-hr.

We are indebted to "Compressed Air" for the facts and illustrations which were furnished by Mr. Wegemann.

Industrial Ventilation*

By Leonard Greenburg

VENTILATION is a problem in the ordinary workroom or assembly hall chiefly and practically entirely during the colder months of the year when windows are as a rule kept shut and artificial heat is used. In 1922, Professor Winslow and the writer presented data (Power Plant Engineering Feb. 1, 1923, page 186) based on the actual examination of conditions prevailing during the winter months in a large number of workrooms which indicated that 68 per cent of the workrooms studied were at the time of examination at a temperature of more than 70 deg. and 15 per cent of the workrooms were 75 deg. and over. That such conditions as these cause a monetary loss, there is little doubt and recent industrial studies by the United States Public Health Service appears to indicate that, due partly to such conditions, also must be ascribed the terrifically high sickness rates from cold among industrial workers. The remedy for this lies in the simple provision of one or more thermometers in the workroom, depending upon the size of the room, and in the intelligent supervision of the windows and heating unit in the workroom.

Ventilation systems for the purpose of cooling rooms should make provision for the handling of very large volumes of air with the inlets preferably near the floor level and the outlets near the ceiling. It may be wise in addition to provide in the neighborhood an inlet of cool air, but not directly bathing the worker. The velocity employed in such cases as this may and preferably should be fairly high. Again it may be well to reiterate that the air stream should not directly strike the worker.

Dusts are present in the atmosphere to a greater or lesser extent at all times, even outdoors after a rainstorm and on the heights of mountains. The atmosphere of practically all workrooms contains an amount of dust greater than that found in homes, and in the atmosphere of those workshops where special dust producing devices are in use, such for instance as crushers, grinders and polishers and sand blast machines, the amount of dust in the air of the workroom may be enormous.

There are three ventilation methods in use for the protection of the worker against industrial dusts, namely the use of hoods of various kinds provided with exhaust pipings and suction exhausts, the use of helmets equipped with air lines for the purpose of supplying the worker with fresh air and lastly the use of enclosures provided with exhaust ventilation by means of which the hazardous dust may be removed.

The removal of fumes or vapors from the atmosphere of the workroom presents practically the same problem as the removal of dust with the possible addition of the heat factor which may be present in the case of vapors, such, for instance, as benzol. Benzol is used in industry chiefly as a solvent and after this purpose is served and the benzol is no longer needed it is allowed to evaporate in the workroom atmosphere. The result of such a practice is that the air may contain considerable quantities of this vapor. The National Safety Council study revealed concentrations from 53 to 4140 parts of benzol per million parts of air. The efficacy of any system for the removal of benzol should be tested by determinations of benzol with and without the protective device in use; such a method would probably yield interesting and important results.

*An abstract of a paper read at the Baltimore Safety Conference held at the Emerson Hotel, Baltimore, Md., Jan. 23, 1925.

Detroit Edison Construction Plans

At the Trenton Channel plant of the Detroit Edison Co., the slow work of finishing this plant will during the present year cost nearly $1,900,000. Part of this sum is due on turbines and the remainder will be for piping, pulverized coal system, track work, landscaping, completing buildings, etc. Later in the year plans will probably be made for the substructure of the second section of the turbine room.

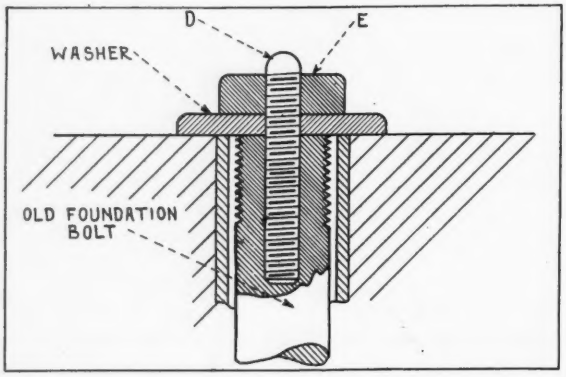
The 3000-kw. hydraulic plant at French Landing on the Huron River is about half complete and will require about $185,000 to finish the job. Improvements and rearrangements will be made at Delray and Connors Creek. The company also has under construction many miles of transmission line work including 120,000 and 23,000-v. overhead lines and conduits and cables for 23,000-v. underground transmission.

Plans for the erection of a direct-current substation and heating plant on Beaubien St. near Madison Ave. call for the expenditure of nearly $1,900,000. Several other substations will also be built. Definite plans have not as yet been decided upon but enough is known about the construction program to say that about $18,000,000 will be invested by the company in new plants and equipment during 1925.

It's as dangerous to overplay your voice as to overplay your hand.

Repairs for a Broken Foundation Bolt

In the accompanying sketch is shown a job which was performed when a 1½-in. foundation bolt on a large generator base broke off under the base at the floor level. The bolts were loose in the foundation, having been installed in casings. Iron wedges were driven in between the bolts



OLD BOLT WAS DRILLED AND TAPPED FOR A ⅞-IN. STUD BOLT

and the sides of the iron pipe casing to prevent the bolt turning while a hole 3 in. deep was drilled and threaded to take a ⅞-in. machine steel bolt D. This bolt was long enough to extend up through the generator base. A large washer and nut, identical in diameter and thickness with the ones used on the 1½-in. bolts, were drilled, and the nut threaded, to fit the ⅞-in. bolt. Although this bolt was not so strong as the larger ones it helped to reduce the strain placed upon the other bolts because of the breaking of the old bolt. The appearance of the equipment was not marred as would have been the case if a regular size ⅞-in. bolt, nut and washer had been used.

Perhaps I should explain that it was possible to lower the generator bolts to the floor level by removing the nuts, thus permitting workers to move the generator to one side without much trouble.

Toronto, Ont. Edward James.

Purification of Feed Water

I note in your issue of March 1, an article entitled "Colloidal Purification of Feed Water."

Hot process softeners can, and do deliver waters containing no more than 0.5 of a part per 100,000 of scale making substances. It, therefore, is not fair to state that better than 5 parts per 100,000 is seldom attained. Many hot process softeners are installed (where better results are not necessary to keep boilers entirely free from scale) which deliver water containing less than 2 parts per 100,000 of incrusting matter.

I take exception to the statement that water softeners leave colloids in the water. Again, that the efficiency of filtration is 80 per cent. In hot process softening there is no appreciable colloidal matter in the water after filtering and certainly not enough to form any scale. Boilers served by hot process softeners are run continuously for periods of 6 mo. without opening them for inspection, or washing and when opened, they are entirely free from scale.

Plants operating at 165 lb. pressure and 200 per cent of rating, keep their boilers on the line for a year of continuous operation without finding any scale in them. Plants operating at 300 lb. absolute pressure, and 200 per cent of rating, make long continuous runs and find their boilers free from scale.

Such statements are misleading and should be qualified. In softening water cold, colloids are generally found in the water after treatment. Filters handling a water treated cold do not remove all of the colloids. If pressures and overloads are high, scale will form where cold systems of treatment are used.

I do not agree with the statement that oxygen causes pitting in boilers. I have in mind a power plant which has been in operation 10 yr., where the oxygen content of the water is as high at times as 0.84 gr. per gal., where there is positively no evidence of corrosion having taken place. I also have in mind two adjoining plants, in one of which the hot-well water from jet condensers is used for boiler feed. The oxygen content of this water is 0.84 gr. per gal. No evidence of any pitting or corrosion is found.

In the adjoining plant surface condensers are used. The boiler feed water contains but 0.4 of a gr. per gal. of oxygen and the pitting is severe. Why will a water with 0.4 gr. per gal. pit, when a water in the adjoining plant containing double the amount of oxygen shows no evidence of pitting?

Chicago, Ill. F. F. Vater.

Siphon Trap Discharges Air from Heating System

On our heating system, when I first took charge of it, the air-relief valves on our radiators were of the adjustable-expansion plug type and were all piped to a main pipe in the engine room. This main exhausts to the atmosphere and the water that comes down with the air drips into a sink. All the valves were practically wide open, so that the steam would blow through a few radiators, fill the whole relief pipe and hold the air back in the rest of the radiators. I had the plugs in every radiator air-valve adjusted, leaving them a quarter of a turn open. That was much better, but every time the steam was shut off the system, the vacuum created by the condensing of the remaining steam would pull air in through the valves.

To stop this I put a check valve on the air main. This was also an improvement, but I noticed that when the steam went on again, a large amount of water would drain

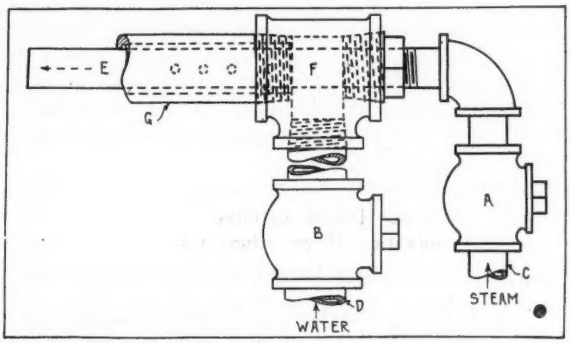
off the pipe into the sink. The water would take up so much space in the pipe that the air was kept back, I made up a siphon trap and placed this in the main air pipe where it would collect all the water. The trap is just a loop or goose-neck whose outlet end has a smaller opening than the pipe the trap is made of. There is also a check valve on the trap to keep air from backing in.

When the loop is filled so that the water starts running out, the siphon action empties the trap and causes a slight suction, which helps to pull the water down and clear the pipe when the steam is off. When the steam is on, the suction pulls both air and water down to the outlet, for the siphon discharges the water just a little faster than it collects.

Brooklyn, N. Y. E. MATZAN.

Emergency Water Heater Was Effective

ON PAGE 301, March 1 issue, R. B. Rowe tells of a water heater which reminds me of a simple outfit I once used for this same purpose. The sketch given herewith



STEAM PIPE IS PERFORATED AND ALSO OPEN AT THE END

explains the idea. A check valve was placed in the steam pipe at A and another in the water supply pipe at B. Globe valves were used on the pipes at C and D. F is a reducing tee and the end of the pipe E is open but four small holes are drilled at three sides. As the water in the delivery pipe G is moving in the same direction as the steam from the open end of the pipe, the operation of the heater is noiseless. Steam issuing from the small holes helps to mix the water properly so that it is heated to a more uniform temperature than is the case when an open end pipe alone is used. In the latter case slugs of hot or cold water are liable to be received at the delivery end of G. A long thread is used on E, which passes through the upper end of the tee from the inside and into the elbow. The use of the check valves prevents steam or water backing up the wrong pipes, should the valves at C and D be open and the valve on the delivery pipe G be closed.

Toronto, Ont. JAMES E. NOBLE.

Neighborly Courtesies

MY FIRST experience as chief in a plant was when I took charge of two 60-in. h.r.t. boilers. The pressure allowed was 125 lb. and the safety valves were set at 80 lb. One engine was a Fitchburg 10 by 12 in. running 120 r.p.m. which was used for lights and for driving a fan used on indirect heating in the lumber drying houses. The other was a Green engine 12 by 24 in. running at 102 r.p.m. used for driving the main shafting through the mill. The third engine was an 1884 pattern Brown, 13 by 36 in. running at 98 r.p.m. and used for driving the sawmill. This engine was only used for a couple of months in the spring.

I held a third-class license at that time and was granted a special license to have charge of this plant. I wish to say I thought I was SOME engineer at that time but later developments proved I could learn a few points here and there. The first morning I went in and started up, I got up steam, as the engineer did his own firing, and then I started the Fitchburg engine. The Green engine I tried my luck on next and this I also got started but when I tried to start the Brown engine, it was another thing. I gave her the steam and she rolled over and stalled on center. I barred her off and tried again to see her go part way and back acting just like an old rocking horse.

I heard a noise at the engine room door and, turning around, I saw an old gentleman standing in the doorway. He said, "Are you the new engineer?"

I was somewhat put out, not being able to start the engine, and more so to have anyone discover me in such a predicament, so I made him some hasty but nasty answer, somewhat like this, "What the blazes do you think I am, a horse jockey?"

The old gentleman only laughed and said, "I think you could start if you would raise up the governor and slip the latch under."

"Well, you know, he might as well have said to crank it up, as you would a flivver, for I did not even see a governor on the thing. But the old man said, "You get a bar and I will show you what I mean," and he did. "Now," he said, "when you shut down, don't forget to put the latch under the governor," and with that he left me.

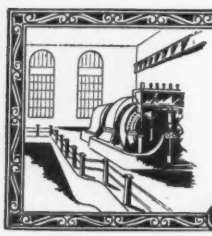
I thought it over during the morning and when he stuck his head in the engine room the next morning, I apologized for the way I had treated him and found out who he was. He was nice about it and told me he was the engineer in the nearby mill and if I ever got into trouble to let him know and he would see what he could do. I shall never forget that kind old man for he helped me many times.

My next difficulty was on a feed pump. It was a Warren duplex pump, piston type, 6 by 6 in. and I could not make it run. One side seemed to work good but the other side had to be barred one way. The injector would not work as there were too many leaks in the suction pipe, so I had to depend on the pump. I had this pump apart many times and packed it, but still it would not run. I met the old engineer who helped me out before, so I asked him what he thought was the trouble. "Well," he said, "you take it apart, take out the piston and rods and I will stop in on my way back from dinner and look it over." His mill ran Saturday afternoon and my place stopped Saturday noon.

Well, you know, he looked at the steam pistons the first thing, and said, "My friend, here is your trouble, the piston ring is worn into the follower plate and has made the ring loose enough, so the steam blows right under the ring and out the other side, consequently, the piston does not get enough pressure behind it to do the work."

I took these pistons to the machine shop, as he told me, and turned enough off the follower plate so the rings would fit snug but not pinch. I put the pump together and started up and found I had a new boiler feed pump.

Worcester, Mass. G. W. PRESCOTT.



QUESTIONS AND ANSWERS

Settings for Return Tubular Boilers

FOUR 72-IN. BY 18-FT. horizontal tubular boilers are under my care. I would like to have some of your readers' opinions on how high they should be set from the grate to get the best results. We have just reset them 30 in. They were set 26 in. in the first place.

Maumee, Ohio. A. B.

Indicator Diagram Shows Unbalanced Load

ACCOMPANYING is an indicator diagram taken on a 16 by 18-in. slide valve engine. This engine is level and well lined up. It is keyed up so there is no slack and the bearings and crosshead are in good running condition. The cylinder measures 16⅛ in. and the piston measures 16 in., or ⅛ in. smaller than the cylinder.

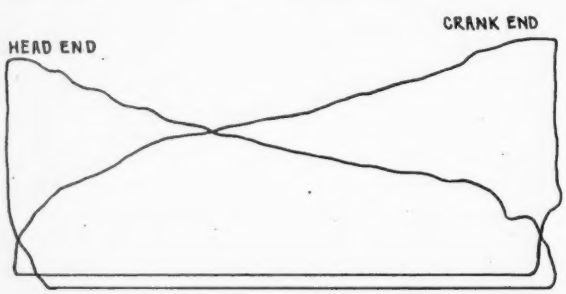


DIAGRAM MADE FROM A 16 BY 18-IN. SLIDE VALVE ENGINE

I would like to know what the clearance should be between the piston and the cylinder. Would a new piston and rings stop the engine from pounding? The valves are now set so the lead is about $\frac{1}{16}$ in. at both ends when the engine is on dead centers. This engine runs over. It is a second-hand machine. W. J.

A. Kent states that the clearance between the piston and the cylinder should be 0.001 in. per in. of cylinder diameter for engines up to 20 in. diameter. Therefore, the diameter of the piston for your engine should be 16.0 minus 16.0 × 0.001, which equals 16.0 minus 0.016 in., or 15.984 in. In measuring the diameter of the cylinder you must be careful that you get the true measurement and not one taken either in the counterbore or at a point where the cylinder is worn. If the cylinder is to be rebored, the piston should be made to fit the cylinder after the finish cut has been made with the boring tool.

It is probable that the kink in the lower end of the expansion line of the head end card is caused either by leakage due to wear or a binding of the valve rod resulting in a temporary lifting of the valve from its seat. The crank end card indicates that the admission may be too late for the proper operation of the engine. The expansion line of the crank end card indicates leakage since it rises above the theoretical expansion line which can be used as a reference. It should also be noted that the back pressure of this card is higher than on the head end; that is, the exhaust line is higher, which may be attributed to leakage past the valve or the piston. The kink in the expansion line is probably also due to leakage.

The best way to detect leakage is to remove the cylinder cover, block the piston at various points in the stroke and test with full steam pressure. It would seem that your next move would be to check up on the wear in the cylinder and then on the valve, reseating the valve and reboring the cylinder if necessary. Since this is an old engine, it would be advisable to figure the strength of the cylinder walls before reboring because the cylinder may have been rebored before and a further removal of metal might leave it too weak to withstand the pressure at which you are now operating.

The head end horsepower is 84 and that of the crank end is 92, making a total of 176 hp.

Boiler Horsepower Computed from Turbine Exhaust Condensate

HOW MANY boiler horsepower were developed to supply a steam turbine under the following conditions? The turbine took steam at 110 lb. gage pressure, exhausting at 5 lb. gage into a commercial heater similar to a surface condenser. The condensate from this exhaust weighed 24,343.4 lb. over a period of 3 hr. and its temperature was 210 deg. F. H. K. S.

A. If the condensate from your exhaust over a 3 hr. period weighs 24,343.4 lb., then you are getting 8,114.4 lb. per hr. Then, since all this condensate came through the turbine in the form of steam, that is the amount of steam that the boiler actually evaporates per hr. You did not state the factor of evaporation of the boiler and in order to find the number of boiler horsepower that must be developed to supply 8,114.4 lb. of steam per hr., under the conditions given, we must find this factor. If the steam contains any moisture, then the factor of evaporation can be found from the following formula:

$$(1) \qquad F = \frac{(X L + H) - H_1}{971.7}$$

In this formula, L is the latent heat of evaporation at absolute boiler pressure; H is the heat of the liquid, corresponding to absolute boiler pressure, and H_1 is the heat of the liquid, corresponding to the feed water temperature; X is the quality of the steam. That is, if there is 2 per cent moisture in the steam, then X will be 0.98. If there is 3 per cent moisture, X will be 0.97 and so on.

Your boiler operates at 110 lb. gage pressure or 125 lb. absolute. You do not state what is done with the con-

densate from the heater, but let us assume that it is used as feed water. Then the boiler would take feed water, let us say, at a temperature of 210 deg.

Using formula (1) assuming 2 per cent moisture, and obtaining the proper values of L, H, and H_1 from the steam table, we have:

$$F = \frac{[(0.98 \times 876.9) + 315.1] - (210 - 32)}{971.7} = 1.025$$

If we assume that the steam from the boiler is dry saturated steam, then X in the above formula becomes 1 and the formula becomes:

(2) $$F = \frac{(H - H_1)}{971.7}$$

in which H is the total heat of steam at absolute boiler pressure. Obtaining the proper values from the steam table, we have

$$F = \frac{1192 - (210 - 32)}{971.7} = 1.04, \text{ for dry steam}$$

This factor of evaporation is the number by which the actual evaporation of the boiler is multiplied to obtain the equivalent evaporation. Now, the boiler is actually evaporating, according to the above conditions, 8,114.4 lb. of water per hr. into steam and since an equivalent evaporation of 34.5 lb. per hr. gives 1 boiler horsepower, then the number of boiler horsepower developed is

$$\frac{8{,}114.4 \times 1.025}{34.5} = 241 \text{ boiler horsepower with slightly wet steam.}$$

$$\frac{8{,}114.4 \times 1.04}{34.5} = 245 \text{ boiler horsepower with dry steam.}$$

In the above computations, heat losses have been neglected and we have assumed, for simplicity, that the condensate entered the boiler at 210 deg. We have also assumed that the boiler supplies steam only to the turbine.

Leakage at Handhole Plates

I HAVE 10 horizontal water-tube boilers on which I have a great deal of trouble with leakage at the handhole plates. I have tried several different kinds of gaskets and have found nothing that comes up with lead gaskets, however, they seem to leak considerably at times, and also leak badly when boiler is being fired up or being taken off the line.

Will you please advise me as to any remedy of which you have knowledge? H. R. W.

A. It may be that the boilers in the plant in question have been in use some few years. It is possible that the handhole sheets which form the gasket bearing surface may have become corroded to some extent and, therefore, be difficult to be made tight. If rubber or composition gaskets have been used in the past, it is possible also that little chunks may have adhered to the handhole sheet of the waterlegs or the flanges of the handhole plates. Our suggestion would be that both the sheets and plates be carefully examined and cleaned.

If there are portions of old gaskets adhered to the face of the waterleg, a tool should be used to scrape them off. If, however, these sheets have corroded they should be faced off so as to give a comparatively smooth surface for the gaskets to bear against.

Leak gaskets can be made tight if care is taken to follow the bolts up after the first time or two that pressure has been reduced. When gaskets of this sort are first fitted, it will probably be found that after they have been pulled up as tightly as possible, the first time they are put under steam the bolts will be loosed, due to the steam pressure squeezing the gasket still thinner, this process being helped along because of a softening of the lead under a higher temperature.

At this time the bolts of the handhole plates should be tightened and any that show a tendency to leak when pressure is reduced should again be followed up. Attention to this point will probably result in an elimination of the complaint about leaking. Lead, having no elasticity, needs to be taken up in this way.

It not infrequently happens that the peculiarities of the water used in a boiler have much to do with the tightness of gaskets. In such cases, the kind of gasket best adapted to those particular conditions can be determined only by experiment.

Oil and Grease Extraction from Exhaust Steam

AT THE PRESENT writing I am endeavoring to figure out an inexpensive way of removing cylinder oil from condensate which comes from our paper machine driers, and which, incidentally, I desire greatly to use for thinning stock in the heaters, in order to eliminate use of high pressure steam. When I say "eliminate," I mean that the cylinder oil must be so completely removed that it will not show up as grease spots in the finished paper. I have tried cloth extractors and have also provided a settling tank from which I draw the water through a goose neck so as always to draw from below the surface but the grease shows up just the same.

In considering what to do next, I have analyzed the cylinder oil used and find that it runs high in tallow. This ingredient is undoubtedly necessary, because the steam is none too dry and it is doubtful if a purely mineral oil would provide proper lubrication. The oil in question has a sufficiently high flash point to guarantee it against breakdown. I believe that the tallow goes into solution and cannot be removed by a cloth filter, neither will the tallow float to the top in settling tank. I fear that the only way out is to filter the condensate through pressure sand filters and then coagulate the tallow by using alum, so that it will float to the top and then draw water from settling tank.

We hear so much about grease extractors and their successful application on boiler feed propositions that most of us take it for granted that they extract the oil. It is my contention that very few really do the trick anywhere near 100 per cent. It is true that they extract sufficient oil so that water may be safely used for boiler feed, but if you are using one, take a squint at the water in your gage glass and note the trace of oil.

As already stated, there is no particular harm in a small amount of oil in boiler feed since boilers are, or should be blown off regularly and this oil has little opportunity of damaging tubes. If, however, you have a proposition similar to the one with which I am wrestling, do not expect too much from a grease extractor.

I would greatly appreciate suggestions as to best way to obtain clean water from exhaust condensate.

Lincoln, N. H. A. P. N.

Condensate from the World's Power Plant

ANALYZED FOR QUICK STUDY AND COMPARISON. BY WILLIAM SIBLEY

Are We Living Off Our Children?

No—we are not living off our children in the sense that we depend on them for our everyday requirements of meat, coffee, or shoes. But we are more and more obligating our children with indebtedness for the municipal, county, state and federal pleasures we have today. When we float a bond issue to pay the cost of a war, to defray the expenses of a soldier's bonus, or build roads, we are living on money borrowed from our children, for they are the ones who will have to retire those bonds.

If you walked into a clothing store, outfitted yourself with a suit of clothes at a cost of $100, then said: "My son here, who is four years old, will pay for this suit when he is 24 years old"—you would be doing personally what you do when you permit your legislature, your county board or your city council, to walk into a "good roads" store, order a thousand miles or so of concrete highways, then say to the bankers who advanced the money: "This loan will be paid back in twenty years"—knowing full well that in twenty years your sons, not yourselves, will be footing the bills.

To just what extent we have obligated ourselves with debt is best shown in figures. They, better than anything else, reveal the extent to which we are living on borrowed capital. While our national wealth increased 72.2 per cent during the 10 years from 1912 to 1922, our total net indebtedness increased almost 300 per cent. In terms of dollars, the increases are as follows:

National Wealth:	
1912	$186,299,664,000
1922	320,803,862,000
Net Total Indebtedness. (Municipal, county, state, federal)	
1912	4,850,400,000
1922	30,845,626,000
State Indebtedness:	
1912	345,942,000
1922	935,544,000
Counties, Cities and Villages:	
1912	3,475,954,000
1922	7,754,176,000

Time was when our taxes paid our governmental expenditures and left a little surplus—when our government lived within its income. The reverse is true now, due in large measure to the heavy bonded indebtedness. In 1890 our taxes amounted to 7.2 per cent of our national income while our governmental expenditures totaled only 7.1 per cent. Since 1890 the trend has been in the opposite direction, as is shown thus:

Year	National Income	Taxes	Expenditures
1890	$12,082,000,000	7.2%	7.1%
1903	20,000,000,000	6.7%	7.7%
1913	34,400,000,000	6.4%	8.5%
1919	66,251,000,000	12.1%	23.4%
1921	50,000,000,000	16.7%	20.5%
1922	58,500,000,000	11.9%	16.5%
1923	67,000,000,000	11.5%	15.0%

Only by governmental divisions do the figures reveal the real reason why our total taxes no longer covers our total governmental expenditures. The following table shows that except for the war period which greatly increased the national expense, the blame for the discrepancy between governmental income and outgo can be laid at the door of the state legislatures, county court houses and city halls:

Year		Taxes (in millions of dollars)	Expenditures
1890	Local	405	487
	State	96	11
	Federal	374	291
1903	Local	706	913
	State	155	182
	Federal	521	475
1913	Local	1219	1844
	State	307	383
	Federal	668	692
1919	Local	2395	3557
	State	570	640
	Federal	5069	11,333
1923	Local	3601	5139
	State	892	1450
	Federal	3223	3459

A study of the preceding figures will show that our state and local governments are chiefly at fault in this piling on of indebtedness and in the mismanagement of credit. Borrowing money through the issuance of bonds is too easy. It is becoming a habit of our city, county and state authorities. And the result is something like this:

In 1912 the per capita indebtedness of the United States was $49.97. Today the per capita indebtedness stands at $283.70. South Dakota's taxes increased 170 per cent in the 5 years from 1915—1920, while her population increased only 4 per cent. North Dakota's taxes increased 200 per cent in the 10 years from 1910 to 1920, while her population increased 12 per cent. Montana's population in the 5 years from 1916 to 1921 increased 10 per cent, but her taxes increased 115 per cent. From 1912 to 1922, taxes in Michigan increased from 11 millions to over 50 millions. Illinois recently voted a hundred million dollar bond issue for the building of roads throughout the state—and those roads will be worn out before the bonds are paid for, as they run for 20 years. In all probability this bond issue will be refunded at maturity for another 15 or 20 years, thus giving children yet unborn the pleasure of paying for roads constructed, used and worn out by us. Including interest, the Illinois roads provided for by this bond issue of $100,000,000 will probably cost, before the issue is returned, in excess of $300,000,000. There is nothing of news in the remark that the financial condition of European governments is not healthy. Here is one reason: Of the $778,005,000 financed in this country by foreign governments during 1924, over $210,000,000 was for the purpose of refunding old debts. The total of all classes of financing in the United States last year was $6,327,086,000—of which almost one billion dollars, or nearly 1/6, was for refunding. Unless we reverse our tac-

tics that 1/6 will grow to a formidable fraction by 1935 or 1940, when many of the road, school, bonus and improvement bond issues mature.

We have developed a terrific credit inflammation—and somebody must pay the fiddler. In business the man who misuses credit, fails. In government, unfortunately, the politician who misuses credit "points with pride" to his supposedly economical administration. When we see 16.5 cents out of every farmer's dollar going for taxes (as against the 8.7 cents in 1910) we wonder how long we can stand the strain—how long it will be before something cracks. We are not paying as we go, and unless we get back to that fundamental principle soon, we shall leave posterity a fine crop of promissory notes as heritage. Just now we are living pretty much off the kids.

1924 Building Activities Exceed All Previous Records

1919	$1,492,947,000
1920	1,608,036,000
1921	1,869,327,000
1922	2,764,077,000
1923	3,391,904,000
1924	3,547,252,000

The foregoing figures represent the value of building activity over a period of six years—last year's construction work breaking all previous records.

In view of the fact that our building activity has shown a steady increase (in spite of periods of depression, minor and major) it would seem that some revision was needed to the theory that the war was entirely responsible for the building shortage. We would rather believe that our normal, pre-war expenditures for buildings which ranged about one billion dollars annually has been permanently raised. This could be due to two major factors: the increasing population in cities and towns (now totaling 63 per cent of our total) and the demand for a higher standard of housing along with the general lifting in standards of living.

Foreign Trade for 1924

Our best customers are, in the order of their importance: Great Britain, Canada, Germany, France, Japan, Cuba, Italy and Holland. Only during 1924, did Great Britain take first place; since the Civil War, Canada always holding first place as a "foreign" customer for American made goods.

The foreign trade of the United States during the past year amounted to $8,200,698,000, which was an increase of almost a quarter-billion over 1923. This foreign trade was divided into exports: $4,590,146,000, and imports: $3,610,552,000.

Those countries from which we chiefly import are, in order: Canada, Great Britain, Cuba, Japan, Brazil, Mexico, Straits Settlements, France, Germany.

Intensify Sales Effort Now

According to the United Business Service, "now is the time to expand sales effort."

Their analysis shows that the whole country, with a few isolated exceptions, is enjoying an increasing trend of business activity which they believe will continue throughout the first half of 1925 and will ultimately approximate a gain of 15 per cent over the business done in the first half of 1924. The "isolated spots" on their sales map for February are shown to be the Rocky Mountain states, Vermont, New Hampshire and the eastern portions of North and South Carolinas. The "best" states are those located in the industrial or manufacturing districts, the "corn belt" and the five states bordering the Gulf of Mexico. Maine, the southwestern states and the Pacific Coast, together with Tennessee and Kentucky are shown to be in the "next best" classification.

Their February 15th forecast says: "Sales executives should fully realize that over supply and foreign competition have not said a final goodbye. Expansion in all lines is going on rapidly, and there is at least a possibility that June or July may usher in a much less favorable combination of sales conditions. We, therefore, recommend broad and extensive selling effort the coming few months, with particular emphasis on types of selling that will cover a considerable territory in a short space of time."

A Few Ways to Save Coal

1. See that fire beds are kept at the proper thickness;
2. Avoid all holes in the fuel bed;
3. Avoid unnecessary leaks of air into the combustion chamber;
4. Repair leaky flues or pipe connections promptly;
5. Watch the brickwork, and fire and dust doors, for air leaks;
6. Make sure all dampers are in good operating condition;
7. Keep the boilers scale-free and the combustion chambers soot-free. 100 lb. of scale will waste 400 lb. of coal every 24 hr.
8. Make sure all baffles are working properly;
9. Open fire or observation doors as little as possible;
10. Make sure of an even flow of raw coal;
11. Maintain normal boiler pressures;
12. Make sure all insulated pipe is covered properly;
13. Keep the feed water at a maximum temperature;
14. Feed water heaters and pumps should be kept in good condition;
15. Control drafts so that safety valves do not waste steam by "blowing off."

Facts Regarding Rail Transportation

Since 1885, freight traffic has increased more than 800 per cent; it has more than doubled since 1905. This increase in freight traffic is considerably greater than the increase in population, which would indicate the marked increase in physical requirements of the present generation over that of our grandfathers.

If railroad traffic increases in the ensuing 10 yr. at the same rate as shown since 1915, it will be necessary for the transportation systems to spend in excess of one billion dollars annually, above the ordinary maintenance, to keep pace with the growth of business.

According to C. H. Markham, president of the Illinois Central Railroad, operating expenses on Class 1 railroads have been reduced nearly five million dollars a day in the last four years. He further states that less than 25 per cent of this decrease in operating charges was effected through the reduction of wages from the war-time levels. This statement is doubly impressive when we realize that since 1920, rail transportation service has been materially bettered.

EDITORIAL COMMENT

A New Idea in Central Station Economics

With the early completion of "Somerset" station of the Montaup Electric Co., described in the leading article of this issue, there will be put into practical operation a new idea in central station economics. As is explained in the article, the Montaup Electric Co. was organized for the express purpose of building the new station, by three existing public utilities, the Fall River Electric Light Co., the Blackstone Valley Gas and Electric Co., and the Edison Electric Illuminating Co. of Brockton, Mass., all of which are now operating efficient steam generating stations in their respective territories. These plants will continue to carry the daily peak loads of their respective companies while Somerset Station will carry the combined base load of the associated companies.

This obviously is the right idea for it makes further use of that valuable factor which in itself is the basis of the whole central station industry—the diversity factor.

Without diversity, the central station could not hope to compete with the isolated plant. It is the fact that A's peak load does not come at the same time B's peak does, that makes it possible for the central station to sell power to both A and B at an attractive rate.

Suppose A and B and all the other customers on a particular system had their peak loads all at the same time—what would it mean to the central station? It would mean that the central station's peak was coincident with and equal to the peak obtained by adding the various customers' peaks together. It would mean that the central station would have to provide generating equipment of sufficient capacity to meet this combined load, even though this peak lasted for only an hour or two out of the twenty-four. During the remaining twenty hours or so, much of the generating equipment of the station would be idle and would earn no return on the investment. It is obvious that under such conditions, a company organized solely for the production and sale of power, could not compete with privately owned plants where the production of power is merely incidental.

Actually, however, the peak loads of the various customers come at different times and as a consequence the generating station need install considerably less reserve equipment to carry loads in excess of normal. This fact that the peaks of the various loads occur at different times is called the diversity of these loads and the diversity factor, as it is called, is of great importance in central station economics. It indicates, so to speak, how many times the capacity of the plant can be used.

In the same way that diversity of the various customers' peak loads is beneficial, so also is the diversity of groups of customers beneficial. In the case of several separate systems, such as those of the three companies associated with the Somerset station, for instance, there is a decided advantage in being able to make use of their diversity. This is one of the things the new Somerset station will accomplish.

Of course, there is nothing new in the idea of combining several generating stations with a large base load station to secure the most economical production of energy. This is done and has been done on various systems throughout the country. What is new in the case of Somerset, however, is the fact that several different companies have cooperated to bring about this result. These companies will not only derive all of the benefits of interconnection, since the tie lines will permit shifting of load from one plant to another in emergency, but they will also procure a considerable portion of their respective power requirements at a rate corresponding to large scale base load operation. The arrangement will be of advantage to all parties concerned, and is one which no doubt will be adopted by other public utility companies.

Greater Economy Has Been Attained

Four channels are open through which improvement in operating economy may be attained. The degree of success, of course, will depend upon the circumstances which will permit any one or all of these channels to be used. In the first place, there is always the possibility of greater economy through persistent effort with the means and equipment at hand; second, worn or obsolete equipment may be replaced; third, additions may be so designed that the overall economy will be improved, and fourth, a new plant may be designed according to the best modern practice.

All of these means may not, or rather should not, be made available until it has been definitely shown that further and worthwhile economy will result from the change. It is logical that no reasonable effort should be spared to be assured, first, that the best obtainable is being gotten from the present layout. It should then be ascertained whether or not a few changes or replacements will give the economic results desired. Load conditions will determine whether an addition should be constructed and if so it should conform to modern standards of economical operation. Finally, the construction of a new plant should guarantee, that with careful supervision, the economy of operation will be consistent with the general problem involved.

These facts have been recognized and put into practice by the public utilities. Improved practices have been established in old plants. Some companies make it a practice to revamp or make economic changes to each of their plants every four or five years. When they have found it necessary to increase the size of an old plant, only the latest equipment has been installed and, finally, when it has been found economically sound to construct a new plant, all reasonable effort has been made to keep the operating cost down.

In 1919 the public utilities developed a total of approximately 24,315,000,000 kw-hr. at an expenditure of 35,100,000 net tons of coal. In 1924, 38,991,000,000 kw-hr. were obtained by the use of 37,483,000 net tons of coal. These are interesting figures from the viewpoint of improvement of economy. In the first place, the power developed in 1924 was greater by 60 per cent than that developed in 1919. This gives some idea of the plant extension work which had been carried on within that period.

By a further study of these figures, it is found that in 1919 it cost 2.9 lb. of coal per kw-hr. and in 1924 it cost but 1.9 lb. per kw-hr.; thus showing a reduction of 34.5 per cent in the fuel required per unit of power developed. This greater economy resulted in a saving in 1924 of 19,495,500 net tons of coal, which is over half of the total fuel bill of 1919. If the rate of increase of power production and economy had progressed uniformly each year from 1919 to and including 1924, the saving of fuel in that period would have exceeded 100,000,000 net tons.

These figures show not only what can be done, but what has been done. They show a truly remarkable performance which has been brought about through persistency of effort and sound economic and engineering judgment in the matter of alterations, replacement and new construction. Corresponding channels and proportionate economies are available to the small producer of power.

Plant Charges Are Established by Designing Engineer

When an engineer puts his approval on the design of a power plant he is virtually signing a note, which somebody else must pay with interest. His reputation as an engineer depends upon the financial success of the projects with which he is associated. He must, therefore, consider with extreme care the proper relation between fixed and operating charges for the plant being designed.

Usually the financial interests specify that the project must indicate a certain minimum return on the investment and, with this figure as a guide, the engineer is given some liberty in the distribution of fixed and operating charges. As a general rule, operating charges can be reduced by the installation of more efficient and higher priced equipment, the relation between the two costs, considering the principal units, taking the form of a curve of the hyperbolic type. So with sufficient data on equipment, the selection is largely a problem in mathematics.

Obviously, it does not pay to run the operating charges down so low that the fixed charges become excessive, nor vice-versa. Consideration must, however, be given to factors of reliability of service and obsolescence, both of which add to the fixed charges without affecting greatly the operating costs.

Although it has always been found good practice to install strictly modern equipment, it is rarely advisable to make an experimental laboratory out of a power plant, or to attempt to establish manufacturing standards by employing special designs for use in a limited number of plants.

Engineers must not lose sight of the fact that engineering is a branch or detail of an industry, the purpose of which is to show a profit on the investment, as is clearly brought out in the article by Mr. Lee on other pages of this issue.

Automatic Control Increases Economy of Small Water Power Plants

Water power development in this country has not been as intensive, on account of certain economic factors, as it has been in Europe, until comparatively recent years. Improvement in various types of turbine blading, however, as well as in mechanical details of construction, has been rapid. But the outstanding feature of present-day hydroelectric practice, it seems to us, is the rapidity with which automatic and remote control equipment is being applied to water power plants, large and small, thus decreasing the number of plant employes required, lowering operating costs and making it commercially possible to tie in comparatively small water powers to large transmission systems without difficulty.

With his characteristic vision, no less a man than the late Charles P. Steinmetz outlined, many years ago, just such a method of interconnection of hydroelectric, steam and oil engine plants as is being extensively used today. He foresaw the economic advantages of being able to install plants of as low as 1000 kw. capacity in almost any location where a demand for power exists. Often the installation of automatic equipment may be the means of justifying the operation of such small plants, on account of the considerable saving in operating costs that may be effected. Steinmetz saw this, but when he first proposed it, the automatic control devices could not be obtained. Electrical engineers have devoted several years and much labor to the devising of reliable means for automatic operation of these plants.

Then, too, there is the question of remote control, used alone or in conjunction with the automatic equipment. Already several stations have been equipped with remote control devices, usually telephonic, by means of which the control station can be informed of such things as the water level of the pond and the fraction of the turbine gate opening, or by which a unit can be started or stopped at will or the governor setting of the turbine changed. Several plants have been installed, communication with which is effected by carrier current radio-telegraphy, popularly known as "wired wireless." At the present time, considerable experimentation is being carried on with wired radio control and, before very long, it will probably be in extensive use.

In all this work, the interest centers chiefly on the development of more or less standardized equipment for automatic and remote control, and in the ingenuity with which this equipment has been worked out. Standby losses and operating costs of such plants are low and it is now possible to use in an economical way much of the power of our smaller streams that has heretofore been wasted.

In past years, a great deal of misunderstanding has been present, not only in the minds of laymen, but also in the minds of many engineers, as to the proper and economical utilization of water power. Here, however, in the development of small automatic hydroelectric plants, tied in with larger systems, is apparently a path toward a commercial solution. This development should be watched with interest by all engineers and advantage should be taken of it, wherever possible, as a means of lowering power costs.

POWER PLANT ENGINEERING DEVELOPMENTS AND NEWS

Three or More Teeth in Contact on Worm Gear Reducer

WORM GEARS have been applied principally in the automotive field, but the De Laval Steam Turbine Co. of Trenton, N. J., has developed a line of worm gear reductions which are applicable to motors and turbines driving such machinery as rotary kilns and coolers, tumbling barrels, agitators, mixers, driers, mills, calenders,

THIS REDUCTION UNIT IS COMPLETELY ENCLOSED IN A HORIZONTALLY SPLIT CASING

paper machinery, machine tools, stokers, cooling tables, transfer rolls, door lifts, fans, elevators and conveyors of all types.

Design of this gearing has been based upon a careful study of the underlying engineering principles, and the gearing is produced by special equipment. The tooth shape is such as to combine a minimum of sliding and a maximum of rolling action between the worm and the gear, and at the same time to realize continuously the greatest area of contact. Undercutting of the teeth is entirely avoided, as the included angle of the tooth is approximately 60 deg., as compared with about 30 deg. as found in older types of gears. As the pressure line normal to the face of the tooth at the pitch circle falls within the base of the tooth, failure can take place only by crushing, rather than by bending. In the De Laval worm gear, three or more teeth are always in contact, giving high load capacity for the size and weight and suiting the gear for heavy duty service.

Owing to the fact that three or more teeth are always in contact, there is a smooth flow of power, resulting not only in absence of vibration and noise but also improving the quality of the work done by the driven machine and prolonging the life of connected machinery. The reduction unit is completely enclosed in a casing, which keeps out dust and moisture. The casing is split horizontally in the plane of the center line of the wheel shaft; the lower half is supported by four substantial feet designed to permit air circulation underneath, this giving additional radiating surface. A large oil reservoir with baffles on the bottom serves to settle out foreign matter from the oil. The wheel shaft is carried on plain bronze bearings, so split as to be easily removable without disturbing the wheel shaft or the couplings. The side thrust of the wheel is carried by a hardened, ground and polished steel plate, which bears against the bronze face of the wheel shaft bearing. The worm may be located either above or below the wheel and is mounted on ball bearings, the one at the rear of the worm being of the double type and designed to carry the combined radial and thrust load, regardless of the direction of rotation of the worm. The inner races are pressed on the shaft and the outer races are clamped both radially and axially, adjusting and locating the worm in the case. The bearing at the forward end of the worm is of the radial type, the inner race of which is pressed on the worm shaft, while the outer race has clearance axially, permitting the bearing to adjust itself to the linear expansion of the shaft. This outer race creeps slowly, which distributes the wear over the race way. The bearings are carried in separate housings so that the case itself is not subject to wear. The worm and wheel and the bearings are lubricated by a splash system.

The worm is made from a low carbon alloy steel forging, which is carburized and heat treated after the threads are cut. The ends of the worm shaft are drawn to remove brittleness and to insure uniform decrease in hardness from the worm threads to the shaft ends. The wheels are made from a special composition of phosphor bronze which gives a low coefficient of friction and possesses toughness and high tensile strength. They are chill cast in dry sand moulds to obtain the maximum hardness. For larger sizes the rims only are made of bronze and are shrunk on solid cast-iron centers to which they are secured by threaded keys riveted in place. To insure a true pitch line the gear wheel is mounted on its own shaft and hobbed on its own bearings, eliminating inaccuracies often found in gears which are pressed on after generation.

De Laval worm reduction gears are made for transmission ratios of approximately 4 to 1 up to 100 to 1 in one step, and for any higher ratio with double reductions. The wheel shaft may be extended to the right or left in both directions. Frames arranged for vertical shaft drive are also supplied. Flexible couplings of the pin and rubber bushing type are used to connect the worm shaft to the driving machine and the wheel shaft to the driven machine.

New Ball-Bearing Spur-Geared Chain Block

RECENTLY an interesting development in the way of a new ball-bearing spur-geared chain block has been placed on the market by The Yale & Towne Mfg. Co., Stamford, Conn. The design provides for two chrome alloy ball bearings to support the load sheave shaft, arranged to take the entire weight of the load and to withstand the shock of all thrust and overload surges. The bearings are located or enclosed in small chambers and provision is made by means of steel and felt washers to prevent dust and grit from entering the bearings. Continuous lubrication of the bearings, the driving pinion, shaft and the driving gears, is also another novel feature.

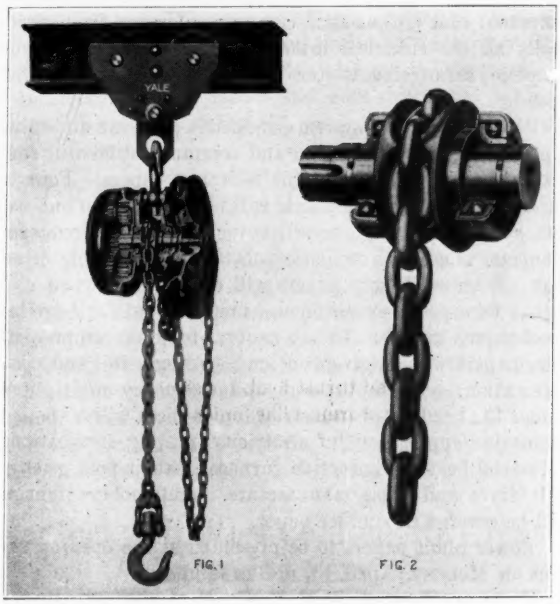


FIG. 1. CUT-AWAY SECTION OF THE SPUR GEAR CHAIN BLOCK
FIG. 2. BALL BEARINGS OF AMPLE SIZE HAVE BEEN PROVIDED

In order to obviate the danger, so common in hoisting, a great deal of attention has been given not only to the size of the parts in the makeup of this chain block but to the material entering into these parts. Obviously it is bad practice to put castings in any part of a chain block where they come in tension. The best possible practice is to use wrought steel parts wherever these parts come in tension in sustaining the load.

The best possible pitch chain should be used for supporting the load. Not only should this chain possess a great elastic limit and tensile strength but it should be as accurate as well-cut gear teeth. A stretched link soon begins to deform the pockets of the load sheaves in which it rides and a poorly-shaped load sheave pocket will quickly begin to deform every link of chain which rides in it.

Ball or roller bearings in a chain block must be able to stand up under the shock which occurs when the load drops or takes up the slack in the load chain. These bearings must be sufficiently liberal in size, and superior in material to take this hammer blow without showing ill effects.

Tests have been made with a 1-T. load lifted so that there was actually 25 in. of slack in the load chain which was attached to the weight. The lever was tripped, allowing the weight to drop for 25 in., taking up the slack in the load chain, thereby subjecting the whole working mechanism of the block, including the ball bearings, to a surge or impact resulting from the accumulated force of 1 T. dropping a distance of 25 in. and then being brought to a sudden stop or jerk at the end of the load chain. Neither the ball bearings nor any of the gears or working parts of the block showed signs of distress after this test. The load chain, however, which was designed to stretch before breaking, had, in this test, stretched nearly 6 in. in a length of 3 ft. or elongated 16⅔ per cent without breaking.

Oil and Gas Power

APRIL 20 to 25 has been designated as Oil and Gas Power Week, when intensive study will be made by some fifteen engineering and scientific bodies of the problem of conserving petroleum and gas resources and the possible substitutes which may be used in place of them.

"The end of petroleum and gasoline as we know them is actually imminent and, whatever may be done to forestall it, will not entirely prevent its coming." Thus is the problem of lubrication and of automobile fuel summarized by D. S. Killefer of the American Chemical Society. The size of the problem is indicated by figures given by Dr. W. F. Durand, president of the American Society of Mechanical Engineers; 340,000,000 hp. in automobiles; 3,000,000 hp. in Liberty engines built for aircraft; millions of horsepower in gas, oil and gasoline engines for stationary power. To contribute toward conservation, mechanical, mining, naval, marine, automotive, chemical, refrigerating and stationary engineers societies and organizations of chemists, oil men, ship designers, safety councils, as well as the U. S. Bureaus of Standards and of Mines and the Geological Survey are joining forces to study what may be done. Some 100 technical meetings will be held during the week of Apr. 20 to 25, in all parts of the country to discuss the problems involved and bring the combined technical knowledge of the country to bear on their solution.

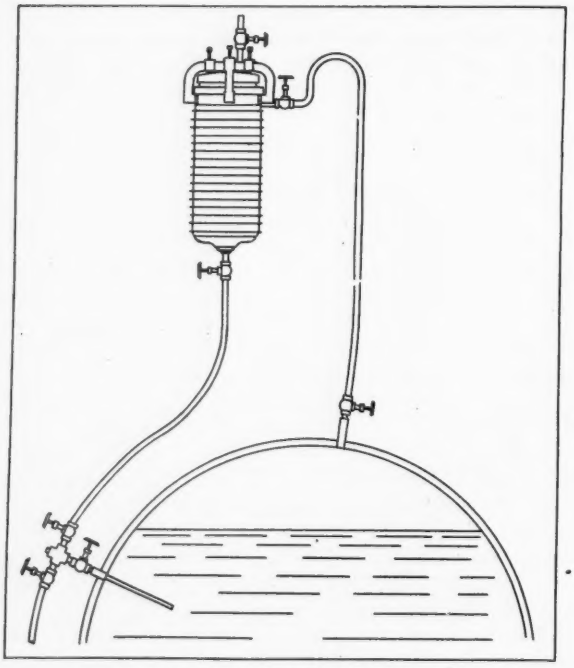
Ninety-four topics have been suggested for consideration, covering economy of production of oil and gas; substitute fuels; heavy petroleum derivatives as fuel; oil engine practice, for land, marine, aircraft, railroad and automobile use; conservation and re-use of lubricating oil; and details of design and operation of internal combustion engines to secure best economy.

Arrangements are in charge of a national committee consisting of W. F. Durand, president Am. Soc. Mech. Eng., chairman; James F. Norris, president Am. Chem. Soc.; J. Edgar Pew, president Am. Petrol. Inst.; C. E. Lucke, W. Trinks, L. H. Morrison and W. E. Bullock, secretary, 29 West 39th St., New York City.

IT IS REPORTED that an experimental tide power plant is being installed by the French government co-operating with a private company at a point near Brest. A sea barrage is built of caissons, the one in the center being 115 ft. long by 73 ft. wide. Reversing turbines will be used, driven by inflow of the tide as well as outflow and a dam will be built to increase storage on the Drowns River. Yearly output of the plant is estimated at 11,000,000 kw. hr. A smaller similar plant is under way on the Arguenon River near St. Malo, also a float type development to utilize wave power at Guyotville, near Algiers.

Apparatus for Prevention of Scale Formation

MEANS OF mechanical treating of boiler feed water have been developed by the Filtrators Co., New York, N. Y. The device used is called a "Filtrator," which consists of an outer cast iron cylinder, and an inner perforated cylinder containing ordinary flaxseed. Live steam from the boiler is piped directly into the Filtrator, permeates the flaxseed, extracts from it a mucilage and condenses, producing the Filtrator emulsion. The pressure inside the Filtrator is at all times equal to the working pressure on the boiler and the production of the emulsion is, therefore, quiet and constant. The emulsion descends by gravity, drop by drop, into the boiler. In the boiler the



METHOD OF PIPING UP THE FILTRATOR

emulsion mixes with the circulating water so that every part of the water in the boiler contains emulsion and assures equal efficiency of action on all surfaces of boiler sheets and tubes.

Filtrator emulsion introduced into the boiler constantly and in sufficient quantity coats with a thin film each particle of any hard matter suspended in the water and prevents it from adhering to the surface of the boiler. These coated particles gradually settle and are ejected from the boiler in the regular blowdowns. The action of the emulsion in the boiler is purely mechanical as it is chemically neutral. This property makes the Filtrator emulsion harmless to the metal of the boiler and its fittings.

It is also claimed that the filtrator emulsion coats the entire inner surface of the boiler with a protective film. In addition to coating scale particles it absorbs acids contained in the water and also absorbs any lubricating oil that gets into the boiler and prevents its harmful effects. It also enters the cracks always existing on the surface of old scale and penetrates between the scale and the boiler metal, gradually loosening the scale which is then thrown off by the circulating water. The husk of the seed is left intact and no oil is extracted from the flaxseed. The perforated container with the exhausted flaxseed can be removed at regular intervals and replaced by a spare container with a new charge.

Attractive Program for A. I. E. E. at St. Louis

A PROGRAM OF unusual interest has been arranged for the coming spring convention of the American Institute of Electric Engineers at St. Louis, April 13-17.

Technical sessions of unusual quality, delightful social features, including a specially attractive program for the ladies, and an excellent hotel and location will all contribute to the success of this convention. An exceedingly competent and enthusiastic committee, drawn from practically all the electrical interests in St. Louis, has made complete arrangements for the enjoyment of all who attend.

Power plants and systems, industrial, marine and mine applications, machine design and communication will constitute the major topics of the technical papers. Four of the most modern power plants will be discussed in one session and another session will cover the use of frequency changers, reactors, automatic substations and cable crossings. Four machinery papers will cover short-circuit currents, two-speed synchronous motors and self-excited synchronous motors. In the general topic of communication, papers will be given on loud speakers, railroad communication, echo suppressors and frequency multipliers. Under the heading of industrial topics there will be papers on marine applications of electricity, mining applications, industrial heating, induction furnaces, babbit pots, rubber-mill drive and glass manufacture. Automobile lighting will be covered in another paper.

Power plant papers to be presented at the opening session on Monday, April 13, are as follows:

Trenton Channel Station, C. F. Hirshfeld, Detroit Edison Co. Data and engineering reasoning leading to the design chosen for the Trenton Channel Plant. The plant will have an ultimate capacity of 300,000 kw. with 50,000-kw. units. Powdered fuel is employed.

Informal discussion on the electrical and mechanical features of the following stations:

Philo Station of the Ohio Power Co., by E. H. McFarland, Beech Bottom Power Co.

Weymouth Station of the Edison Electric Illuminating Co. of Boston, by I. E. Moultrop.

Cahokia Station of the Union Electric Light & Power Co. by H. W. Eales.

Transmission problems will be taken up at the Power Systems Session on Tuesday, April 14. The papers to be presented at this session are as follows:

Interconnection of Systems with Frequency Changers, H. R. Woodrow, Brooklyn Edison Co. A discussion of the 35,000-kv.a. synchronous-synchronous frequency changer which ties together the 60-cycle and 25-cycle systems of the Brooklyn Edison Co.

Eight Years' Experience with Protective Reactors, James Lyman, L. L. Perry and A. M. Rossman, all of Sargent & Lundy. Results of eight years' experience with reactors in operation in three large power stations. The action of the reactors in a number of cases of actual trouble is analyzed.

Mississippi River Crossing Crystal City transmission Line. H. W. Eales and E. Ettlinger, both of the Union Electric Light & Power Co.

Application of Automatic Control to Substation Apparatus, W. H. Millan, Union Electric Light & Power Co. This paper contains suggestions for eliminating some of the troubles which may develop in the automatic operation of substation equipment. It applies particularly to alternating-current distributing substations and direct-current substations feeding heavy Edison networks.

A number of excellent inspection trips are planned. The great number of the industries of St. Louis offers a wide variety of things to be seen. Power plants and systems, many industrial establishments, telephone systems, etc., offer a wide diversity.

The Cahokia plant of the Union Electric Light & Power Co. will of course be of great interest. A special trip will be made to this plant, probably Wednesday afternoon. A number of other trips also will be arranged. A sightseeing trip for ladies and gentlemen will be made Wednesday afternoon through some beautiful sections sections of the city.

Southwestern Utilities Merge

ANNOUNCEMENT has just been made of the formation of the Electric Power & Light Corp. which will take over the assets of the Utah Securities Corp. and also the common stock and certain other securities now held by the Electric Bond & Share Co. of the New Orleans Public Service, Dallas Power & Light, Dallas Railway, Texas Interurban Railway & Power Securities Companies. The last named company owns the common stock and other securities of the Idaho Power Co. The companies serve 253 communities and have 3541 mi. of transmission lines.

Kentucky Utilities Co. Reports Greatly Extended Service

THE NUMBER of towns served by the Kentucky Utilities Co. was increased more than 48 per cent during 1924 according to an announcement recently made by the company. In extending its service some 500 mi. of transmission lines were constructed in Kentucky, Tennessee and Virginia. The company now has 955 mi. of high-voltage transmission lines which link on the east with the Old Dominion Power Co., on the west with the Central Illinois Public Service Co. and on the north with the Interstate Public Service Co.

News Notes

ARTHUR D. LITTLE, president of Arthur D. Little, Inc., of Boston, was elected to succeed Charles H. Herty as chairman of the Advisory Committee of the Exposition of Chemical Industries at a recent meeting of the committee. Charles H. Herty, who resigned from the chairmanship of the Advisory Committee owing to the pressure of other duties, is president of the Synthetic Organic Chemical Manufacturers' Association of the United States. He has been chairman of the committee for ten years, serving since the inception of the Chemical Exposition in 1915. He remains a member of the committee. As an author of scientific works, and as a research pioneer, especially in the chemistry of the paper industry and in the development of artificial silk, Arthur D. Little has been most widely known during the past two decades. Dr. Little has been a member of the Exposition Committee for the past ten years. This, the Tenth Exposition of Chemical Industries will be held at the Grand Central Palace, New York, September 28 to October 3, 1925.

IN COMPLIANCE with the Constitution of the American Institute of Electrical Engineers, the Board of Directors held a meeting in New York on March 13, at which the report of the Committee of Tellers of its canvass of the nomination ballots cast for candidates for the Institute offices falling vacant July 31, 1925, was presented. As a result of this meeting, the following candidates have been selected: For President, Dr. Michael I. Pupin, Columbia University, New York; for Vice-Presidents, Middle Eastern District, Arthur G. Pierce, Cleveland, Southern District, W. E. Mitchell, Birmingham, North Central, Herbert S. Sands, Denver, Pacific District, B. M. Downing, San Francisco, Canadian District, W. P. Dobson, Toronto; for Managers, M. M. Fowler, Chicago, E. C. Stone, Pittsburgh and H. A. Kidder, New York; for Treasurer, George A. Hamilton, Elizabeth, N. J.

THE CARNEGIE STEEL CO. recently ordered a number of electric motors and generating equipment for use in the McDonald Mills at Youngstown, Ohio. This equipment, which will be furnished by the General Electric Co., includes two 15,000-kw. turbine generators with direct connected exciters; five 6600-v., adjustable speed, mill type induction motors ranging from 1125 to 2200 hp., and two 2500-hp., 6600-v., constant speed, mill type induction motors. The adjustable speed motors are to be furnished with Scherbius speed regulating equipment similar to control of the same type now installed in other mills of this company.

W. A. LACEY, chief engineer of the Eastern Massachusetts Railway Co. power plant at Lowell, Mass., has resigned to accept a position as chief engineer and master mechanic with a manufacturing firm at Worcester, Mass. G. J. Knowlin, formerly supervisor of power for Hollingsworth Vose Paper Co., has been appointed chief engineer of Eastern Massachusetts Railway Co. power station at Lowell, Mass.

THE VERMONT HYDRO ELECTRIC CO., the Rutland Railway Light & Power Co. and the Pittsford Power Co., with headquarters at Rutland, Vt., have been consolidated with the Twin State Gas & Electric Co., serving parts of Vermont and New Hampshire. The controlling interest in the three Rutland concerns was transferred by the General Gas & Electric Co. of New York to Insull Bros. of Chicago.

THE HILL CLUTCH MACHINE & FOUNDRY CO., of Cleveland, Ohio, has recently appointed T. L. Rose & Son as its representative in Pittsburgh and adjusted territory. Mr. Rose has been prominently identified in the power transmission field for more than 25 yr. and has excellent facilities for representing the comprehensive line of Hill clutch mill equipment.

WITH THE OPENING of a district sales office at 160 N. La Salle St., Chicago, the American Cable Company announces the appointment of W. H. Slingluff to handle sales of the company's wire rope, fittings and other standard wire rope products in the midwestern states.

BURD & GIFFELS, municipal and power plant engineers, Grand Rapids, Mich., announce that Charles A. Hamilton

has become associated with them as a partner. The firm name has been changed to Burd, Giffels & Hamilton.

THE GEO. H. ALWINE Co., Omaha, Neb., has been appointed sales representative for the Bundy Steam Trap Co., Nashua, N. H. The appointment of W. L. Sullivan, Tulsa, Okla., to represent the company in the states of Oklahoma, Northern Texas and Southern Kansas, is also announced.

THOMAS E. DURBAN has, after an absence of 7 yr. from the Erie City Iron Works, returned to that organization in an advisory capacity, giving special attention to sales promotion. In his new capacity he will devote his time to the development of steam power equipment in all its allied lines.

W. C. DAVIS, of the sales department, of the Ohio Injector Co., has been promoted to assistant sales manager with headquarters at Wadsworth, Ohio. Mr. Davis has been with the Ohio Injector Co. about 4 yr. and before that time was in the mechanical sales department of the B. F. Goodrich Rubber Co., Akron, Ohio.

HOMESTEAD VALVE MANUFACTURING Co. announces the following distributors as having been appointed agents for the Homestead products: W. A. Case & Sons, Rochester, N. Y.; The Fulton Supply Co., Atlanta, Ga., and Charles A. Setzer, Manufacturers' Agent, Charlotte, N. C.

WM. W. NUGENT & Co., INC., manufacturers of lubricating devices, installed Nugent patented telescopic oiling devices on the crosshead pins and eccentrics of the Allis-Chalmers crank and flywheel pumping units which were recently erected at the new pumping plant at South Bend, Ind.

THE BOARD OF WATER COMMISSIONERS in the City and County of Denver, Colorado, has recently placed an order with the De Laval Steam Turbine Co. for one 15,000,000-gal. De Laval centrifugal pump, driven through reduction gears by a steam turbine, together with condenser and auxiliaries complete. This unit will be installed in the Denver Water Works System and is the fourth De Laval unit purchased by the City of Denver.

Books and Catalogs

ELECTRICAL ENGINEERING, by L. A. Hazeltine; 625 pages, size 6 by 9 in., cloth; New York, N. Y., 1924.

This book represents an attempt to cover in a single volume the essential elements of electrical science and of its applications to the various branches of electrical engineering. It is a book which deals with principles and circuits rather than in machines; in fact, there are only three chapters devoted to electrical machinery. It is essentially a text book for use in college where it will be supplemented by the elaborations of a teacher, or as a reference book for readers having a general familiarity with the subject.

The first chapter is devoted to the basic ideas of physics which must underlie the electrical branches. At the very start attention is directed to the concept of energy. The next three chapters take up the fundamental branches of electrical physics—electric conduction, electrostatics, and electromagnetism. The method followed has been to describe the basic experimental facts, to introduce such physical concepts as will facilitate the verbal expression of these facts in concise laws, and to apply these laws to specific cases.

The electron is introduced in Chapter VII, after the fundamental laws have been thoroughly discussed. The author is of the opinion that it is a mistake to introduce the electron at the very beginning, as has sometimes been advocated. The fundamental electrical laws, he states, are certainly most familiar through everyday experiences and to begin by assuming the existence of electrons whose actions are sometimes quite complicated, seems like arguing from the unknown. Nothing can ever make the electron quite as vivid and real to the student as electrical friction in a wire, electrical elasticity in a condenser, or electrical inertia in a coil. In this book, after the fundamentals have been covered and the laws governing charged particles have been formulated, then the electron is introduced.

For those wishing an unusually comprehensive reference work on electrical engineering the book is certain to find great popularity. It is well written and well illustrated.

UEHLING INSTRUMENT Co. of Paterson, N. J., has just issued Bulletins 118 and 118-A, describing the Apex CO_2 Recorder, which operates on the pneumatic principle.

WHAT IS voltage drop control? What extraordinary thing does it do? Can I use it in any of my work? Is it worth while for me to adopt it? These are topics discussed in a 12-page bulletin just issued by the General Electric Co. entitled "The Voltage Drop Control System."

LEEDS & NORTHRUP Co. of Philadelphia, has issued two bulletins: No. 533, describing the "Burrows Permeameter" and the "Epstein Core Loss Apparatus" and No. 984, the Vreeland Oscillator. These are all laboratory instruments of the highest precision.

CONVENIENT TABLES of air pressure and fan data, water pressure, friction loss in pipes, structural design data and the commonly used electrical and mechanical information are all compressed into a suitable form for emergency calculations in a new pocket size Manual for Engineers recently published by the University of Tennessee.

THE CLEVELAND CRANE & Engineering Co. of Wickliffe, Ohio, has issued an interesting 8-page circular showing applications of the Cleveland Hand and Electric Tramrails. While these tramrails are essentially for industrial handling, they are applicable to the power plant in the handling of coal and ashes.

W. A. JONES FOUNDRY & MACHINE Co. of Chicago, Ill., has just issued a new catalog, No. 30, which contains 448 pages on Power Transmission data, including cut gears, cast gears, spur gears, spur gear speed reducers, enclosed worm gear drives, cast-iron pulleys, friction clutches, sprocket wheels, hangers, pillow blocks, couplings and rope sheaves.

HANNA "PINCH BUG" Riveters are described in Bulletin R-201, now being distributed by the Hanna Engineering Works, 1765 Elston Ave., Chicago. These riveters have been developed for use on work requiring rapid action and adaptability in getting on and off rivets, a driving speed of 25 rivets per minute on straight runs not being uncommon.

DEFINITE indication of the load on a station shown in the boiler room, the turbine room, the load dispatcher's room and other important locations is of great assistance in operation of a plant with best economy. In a new bulletin issued by Chas. Cory & Son, Inc., 183 Varick St., New York, the Cory indicating systems with automatic or manual control of present load and manual control of expected load are described and illustrated. Copies may be had on request.

Sparks from the Advertising Pages

Where Buyers and Sellers Meet

Machines that Make Men

Men have made machines until the multiplication of them is remaking the race of men.

Today many houses contain more mechanical devices than most of the so-called factories of a few generations ago and use more power for domestic purposes than the old-time craftsmen's shops.

Since this new era of power development began, there have arisen those who deplored the tendencies of this machine age and accused it of making machines out of men.

Man's rise in the scale of created beings has been strictly in accordance with the development of his capacity to co-operate.

Future development of civilization waits only on further development of this capacity.

First compelled to get together to survive, men were compelled to wage a ceaseless fight.

Next, having wrested from Nature a more dependable sustenance, the first fruits of co-operation were the beginnings of wealth and a modicum of leisure left over from a hand-to-hand existence.

All the centuries that came between that time and this have seen men rise to the greatest heights of co-operative effort, only for warfare that was instigated to seize wealth.

In the last decade we have learned much about war and much about wealth.

Steadily power, applied through machines, has been adding to wealth. Following a war in which machines played an unprecedented part, there has come a time when mechanical power in peaceful production has leaped ahead at a rate beyond anything heretofore seen.

Rules that economists laid down, though undisputed, never became part and parcel of the thoughts of the majority.

Now there is permeating humanity a conviction of the indispensability of co-operative effort and common responsibility.

Power and the conditions it lays down are doing this. Pouring its ceaseless force in ever increasing quantity into the common life of the people, power is lightening the day's work, increasing the conveniences and adding to the leisure of everyone of high or low degree.

It is more effective as a distributor of wealth than all the social, economic and political schemes ever tried by man.

There never was an economic force which in so great a measure tended to make all men free and equal as mechanical power. By its nature it lifts the heaviest burdens first, takes over the most grinding toil and the most hazardous work.

Now its ever-growing might has passed as far beyond the period of aggrandizement as political power has passed beyond the control of dynasties.

For power is so tremendous that its future development must ever be more and more by the people; its control will be more and more in the hands of its users and its captains acting as administrators.

As an economic factor it gives wealth and leisure; as a social factor it more equably distributes these benefits, and, too, power helps to offer new ways to live that part of life it has released from bondage.

Millions ride in ease amidst the pleasant places of the earth, because power forges, shapes and drives for them vehicles that are magical compared with all the king's coaches and horses.

Art and beauty in every form; knowledge and the opportunity to exercise intelligence, these power prints and transmits to the multitude in greater measure than that enjoyed by ancient patrons of the arts.

Nor has power failed to provide the sterner requirements necessary to make character in the race it both serves and shapes.

Discipline it gives, for along with regularity and dependability of rewards, it requires like qualities in those who work with it. Who would say that punching a time clock is not more character forming than the prod of a bayonet at the bugle call?

To initiative it gives a thousand opportunities to every one offered in the ages without mechanical power. The smallest improvements in its generation or application throughout their countless ramifications is quickly recognized.

No fear or favor of other men can hold a man back or forward his fortunes in this service to mechanical power.

Successful power plant men work along these lines and look upon their work, from firing fuel to selecting equipment, as a public trust.

Makers of machines, supplies and equipment, design, manufacture and distribute their products not for the immediate sale alone, but for their greater service to mankind.

Power-generating, race-building, man-making machines are advertised in these pages.

Machinery, Equipment and Supplies Used In The Production and Transmission of Power

Under the heading of each product listed will be found the names of the manufacturers of that product. The index to advertisers, next to the back cover, gives the page numbers on which the manufacturers' descriptive advertisements appear.

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Hercules Float Wks., Springfield, Mass.

AIR COMPRESSORS.
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American Well Works, Aurora, Ill.
Dean Bros. Co., Indianapolis.
De Laval Steam Turbine Co., Trenton, N. J.
Murray Iron Works Co., Burlington, Iowa
Worthington Pump & Machinery Corp., New York, N. Y.
Yeomans Bros., Co., Chicago, Ill.

AIR WASHERS.
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Cooling Tower Co., Inc., The, New York.

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Hills-McCanna Co., Chicago, Ill.
Huyette Co., Inc., The Paul B., Philadelphia, Pa.
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Hofft Co., The M. A., Indianapolis, Ind.
Lavino & Co., E. J., Philadelphia
Liptak Fire Brick Arch Co., Mexico, Mo.
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Conveyors Corp. of America, Chicago.
Detrick Co., M. H., Chicago.
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ASH TANKS.
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Magnolia Metal Co., New York.

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Link-Belt Co., Chicago, Ill.
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De Laval Steam Turbine Co., Trenton, N. J.
Terry Steam Turbine Co., The, Hartford, Conn.
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King Refractories Co., Inc., Buffalo, N. Y.
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McLeod & Henry Co., Troy, N.Y.
Plibrico Jointless Firebrick Co., Chicago, Ill.
Queen's Run Refractories Co., Inc., Lock Haven, Pa.

To Find the Manufacturers' Advertisements of Products Listed Here, See Index Page 148

BOILER SKIMMERS.
Sims Co., The, Erie, Pa.

BOILER TUBE CLEANERS.
Lagonda Mfg. Co., Springfield, Ohio.
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Edge Moor Iron Co., Edge Moor, Del.
Erie City Iron Works, Erie, Pa.
Freeman Mfg. Co., Racine, Wis.
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Murray Iron Works Co., Burlington, Iowa
Union Iron Works, Erie, Pa.
Webster, Howard J., Philadelphia, Pa.
Wickes Boiler Co., The, Saginaw, Mich.

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Sweet's Catalog Service, Inc., New York

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Littleford Bros., Cincinnati

BRUSHES, DYNAMO & MOTOR.
Dixon Crucible Co., Jos., Jersey City, N. J.

BRUSHES, GRAPHITE.
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BRUSHES, WIRE.
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BUCKETS, CLAMSHELL.
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CARRIERS, PIVOTED BUCKET.
Webster Mfg. Co., The, Chicago

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King Refrac. Co., Inc., Buffalo.
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Plibrico Jointless Firebrick Co., Chicago, Ill.
Queen's Run Refractories Co., Lock Haven, Pa.
Quigley Furnace Spec. Co., New York.

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King Refrac. Co., Inc., Buffalo.
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Plibrico Jointless Firebrick Co., Chicago, Ill.
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Fairbanks-Morse & Co., Chicago.
Frederick Iron & Steel Co., Frederick, Md.
Link-Belt Co., Chicago, Ill.
Stearns Conveyor Co., The, Cleveland, Ohio.
Stephens-Adamson Mfg. Co., Aurora, Ill.
United Conveyor Corp., Chicago.
Webster Mfg. Co., The, Chicago.